Conservation Assessment of *Zieria odorifera* subsp. *warrabahensis*

Eren Delgado[1] 2/08/2018
1, Science Division, NSW Office of Environment and Heritage

***Zieria odorifera* subsp. *warrabahensis* Duretto and P.I. Forst (Rutaceae)**
Distribution: Endemic to NSW
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Not Listed

Conservation Advice: *Zieria odorifera* subsp. *warrabahensis*

Summary of Conservation Assessment

Zieria odorifera subsp. warrabahensis was found to be eligible for listing as Critically Endangered under criteria B1+2ab(iii)(v) and C2a(ii), in addition to Endangered under criterion D.

The main reasons for this species being eligible are: i) the species has a very highly restricted geographic distribution, with both an extent of occurrence (EOO) and area of occupancy (AOO) of 4 km²; ii) there is a very small population size with an estimated 100 mature individuals in total occurring within a single population; iii) there is a continuing decline in the quality of habitat and number of mature individuals due to grazing by feral and domestic herbivores; iv) there is considered to be only a single location with respect to the threat of adverse grazing impacts.

Description and Taxonomy
Duretto and Forster (2008) describe four subspecies within *Zieria odorifera* and they suggest that the threat status varies across each subspecies.

Zieria odorifera subsp. *warrabahensis* Duretto & P.I.Forst. (family Rutaceae) is described as "Erect shrub to 40 cm tall. Branches with a moderately dense indumentum of mainly stellate and some bifid hairs. Leaves sparsely pilose sometimes with hairs concentrated on midribs; petioles 1–1.5 mm long, glandular verrucose; terminal leaflets narrowly elliptic to oblanceolate, 2.5–5 × 1–3 mm, margins slightly to obviously glandular dentate, adaxial surface not glandular verrucose. Inflorescence usually longer than the subtending leaves, 1–3-flowered; peduncle 3–5 mm long, sparsely stellate hairy; pedicels 1–1.5 mm long, with 1 mm, abaxial surfaces glabrous or with a sparse indumentum of minute stellate hairs. Petals c. 2.5 × 1.2 mm, adaxial surface sparsely pilose, abaxial surface with a dense stellate indumentum. Gynoecium glabrous. Cocci and seed not seen." PlantNET 2018.

Zieria odorifera subsp. *warrabahensis* was first collected by Dr. John Hunter in 1995 on a private property near the north-eastern edge of Warrabah National Park. In 2006, a second collection (11 years later) was taken by Lachlan Copeland from the same general area. In both instances, the plants were tentatively identified as *Zieria odorifera* (Copeland pers. comm. 2017). After a close examination of all specimens in the *Zieria odorifera* complex, Duretto and Foster (2008) split the species into four subspecies with one of them as *Z. o. warrabahensis* (Copeland pers. comm. 2017).

Distribution and Abundance
The NSW Scientific Committee (2018) state that "*Zieria odorifera* subsp. *warrabahensis* is endemic to New South Wales (NSW) and is known only from a limited area in and near Warrabah National Park west of Armidale in northern NSW. It is found in both heath and *Eucalyptus prava*/*Callitris endlicheri* layered woodland on granite outcrops (Duretto and Foster 2008; PlantNET 2016; L. Copeland *in litt*. May 2016, November 2016, January 2017)."

"*Zieria odorifera* subsp. *warrabahensis* is known from only two herbarium collections made c. 2.7 km apart. Two surveys for this taxon in October 2006 determined that the subspecies is confined to a small area in Warrabah National Park and adjacent private property and it is apparently absent from other areas of the park that contain suitable habitat. The population is estimated to be c. 100 individuals (L. Copeland *in litt*. May 2016; November 2016, January 2017). The number of mature individuals is therefore projected to be very low." Approximately 70% of the plants observed occur in Warrabah National Park while the 30% remining occur on private land (Copeland pers. comm. 2017).

Zieria odorifera subsp. *warrabahensis* is a very highly restricted taxon currently known from just a single population. Observations by Copeland (pers comm. 2017) during two visits and approximately 15 years surveying the park, suggest that this species is scattered across a few hectares. In addition, the species is absent from the area of apparently suitable habitat to the west and south-west in the core of Warrabah NP. Although there are a few granite outcrops in Warrabah NP only a small number are large and flat enough to have well developed granite heath species, and certainly the species is not widespread or common where it occurs (Copeland pers. comm. 2017).

The geographic distribution of *Zieria odorifera* subsp. *warrabahensis* is very highly restricted. The area of occupancy (AOO) is estimated to be 4- 8 km^2, based on the species' occupying one to two 2 x 2 km grid cells, the spatial scale of assessment recommended by IUCN (2017). The extent of occurrence (EOO) is also 4-8 km^2. The EOO is reported as equal to AOO, despite the range of the species, measured by a minimum convex polygon containing all the known sites of occurrence, being less than AOO. This is to ensure consistency with the definition of AOO as an area within EOO, following IUCN Guidelines (2017).

Ecology

Zieria odorifera subsp. *warrabahensis* is a low growing perennial shrub reaching a height of about 30-40 cm in favourable conditions (e.g. without excessive grazing). Flowers and fruits have been collected in September and October (Copeland pers. comm. 2017). There is very limited information known about the biology of this species.

Pollinators:

Armstrong (2002) suggests that "Apart from the inconspicuously flowered species (*Z. minutiflora* and *Z. pilosa*) that appear to be modally self-pollinating, *Zieria* flowers are insect-pollinated (entomophilous) (Armstrong 1979). Nectar and pollen seeking flies and pollen seeking beetles were the most frequently observed vectors of *Zieria* pollen. More rarely, bees (*Leioproctus*: Colletidae, *Homalictus*: Halictidae) have been observed visiting the flowers of *Zieria* taxa".

Seed dispersal and viability:

Zieria odorifera subsp. *warrabahensis* has a dry/hard fruit and small hard seeds (Copeland pers. comm. 2017). It does not appear to have conspicuous adaptations to assist seed dispersal.

Sclerophyllous species of Rutaceae, generally from the heaths and dry forests, have a limited dispersal ability (Westoby *et al.* 1990, Auld 2001). At maturity, *Zieria* seeds are released from fruits ballistically (the fruit is a schizocarp capsule) which facilitates a limited short distance dispersal of the diaspore, a few meters away from the parent (Westoby *et al.* 1990, Auld 2001, Armstrong 2002). This is followed by secondary seed dispersal primarily by ants (Myrmecochory) (Auld 2001). Myrmecochorous species have seeds with attachments that are attractive to ants (Westoby *et al*. 1990, Armstrong 2002), serving as both a handle for ants to move seeds and as a food reward for them (Auld 2001). Not all movement of seeds by ants may be beneficial to plants. Some ant species

may consume much of the seed they move (Hughes & Westoby 1992) while other seeds may be buried in 'unsafe' sites (Auld 1986a) and such seeds are effectively lost from the soil seed bank (Auld 2001).

Fire response and germination/ seed dormancy:
"The response to fire of *Zieria odorifera* subsp. *warrabahensis* is not well documented, however, it is likely to resprout following fire given that this behaviour has been documented for the closely related *Zieria odorifera* subsp. *williamsii* (Clarke *et al.* 2009)" (Copeland pers. comm. 2017). *Zieria odorifera* subsp. *warrabahensis* is likely to maintain a persistent, soil-stored seed bank as per other Rutaceae species. Auld (2001) suggests that "members of the Rutaceae are likely to have persistent soil seedbanks with germination linked to fire, except perhaps for species in rainforest or rainforest margins (where the nature of possible seedbanks is unknown)."

Threats
The NSW Scientific Committee (2017) state that "Threats to the population include grazing by feral goats and inappropriate fire regimes (L. Copeland, *in litt*. May 2016, January 2017). The population's limited extent makes it highly susceptible to localised events such as disturbance and weed invasion, in addition to clearing on private land.

Grazing:
Zieria odorifera subsp. *warrabahensis* is susceptible to grazing and browsing disturbances by domestic stock and herbivores (Copeland pers. comm. 2017). Copeland surveyed the species across its range in October 2006, over two separate trips. He observed a number of plants were browsed, with leaves damaged, and some plants reduced to broken stems with barely any leaves remaining. Copeland (pers. comm. 2017) has also observed this pattern for numerous populations of the closely related *Zieria odorifera* subsp. *williamsii*. A fence forming the boundary between Warrabah NP and the adjacent private property divides the population, however, a similar level of grazing was observed on both sides of the fence. The private property is subject to regular sheep grazing, while in the National Park, feral goats are prolific. The rocky outcrop where the subspecies occurs is known to have a high concentration of feral goats and is littered with many of their scats, suggesting ongoing goat activity (Copeland pers. comm. 2017). In addition, feral goats can cause significant habitat degradation by removing or destroying vegetation, trampling, decreasing soil stability and contributing to erosion (NSW Scientific Committee 2004).

Inappropriate fire regime:
Potentially both high and low frequency fire may be a threat to *Zieria odorifera* subsp. *warrabahensis.* While individuals of this species are likely to survive a fire (resprout), repeated burns in a short interval may kill the plants, especially if their resources are already depleted as a result of frequent grazing (Copeland pers. comm. 2017). At the same time, fires may promote germination and recruitment in the species as occurs in other members of the genus (Auld 2001). Hence, an absence of fire may limit population replacement unless the species can recruit new individuals in the absence of fire.

While there have been several fires in Warrabah National Park, most of the park has not been burnt for at least 29 years (NSW NPWS 2003). NSW NPWS (2003) suggest that "Evidence of fire within the park is very limited and there appears to have been a regime of infrequent fires since European settlement of the area. This view is partly supported by significant stands of White Cypress Pine, a species very susceptible to fire, and the dense, mature stands of grey tea tree and Cassinia currently present throughout the park."

Currently there is insufficient information to assess any adverse impacts of fire directly on *Zieria odorifera* subsp. *warrabahensis*. However, it is expected that "the absence of fire in the heathland communities of the park may lead to a decline in the number of species. Unburnt woodland communities will also reach the lower end of their maximum fire-free thresholds in the next few years." (NSW NPWS 2003).

Assessment against IUCN Red List criteria

For this assessment, it is considered that the survey of *Zieria odorifera* subsp. *warrabahensis* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A Population Size reduction
Assessment Outcome: Data Deficient
Justification: To be listed as a threatened under Criterion A, the species must have experienced a population reduction of at least 30% over three generations or 10 years (whichever is longer). The population size of this species is extremely low. The census data available is very limited, and there is no evidence to determine whether or not there has been a reduction of this species although it is likely given that some plants occur on private land with a long history of sheep grazing (Copeland pers. comm. 2017). There is insufficient data in regards population size trend and generation length to assess this species under this criterion.

Criterion B Geographic range
Assessment Outcome: Critically Endangered under Criterion B1ab(iii)(v)+B2ab(iii)(v)
Justification: The geographic distribution of *Zieria odorifera* subsp. *warrabahensis* is very highly restricted. The area of occupancy (AOO) is estimated to be 4-8 km^2, based on the species' occupying one to two 2 x 2 km grid cells, the spatial scale of assessment recommended by IUCN (2017). The extent of occurrence (EOO) is also 4-8 km^2. The EOO is reported as equal to AOO, despite the range of the species, measured by a minimum convex polygon containing all the known sites of occurrence, being less than AOO. This is to ensure consistency with the definition of AOO as an area within EOO, following IUCN Guidelines (2017).
A species with an extent of occurrence (EOO) less than 100 km^2 qualifies for the Critically Endangered threshold. A species with an area of occupancy (AOO) less than 10 km^2qualifies for the Critically Endangered threshold.

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 number of locations is: one (CR), ≤5 (EN), or ≤10 (VU).

   Assessment outcome: sub criterion met at Critically Endangered threshold.
   Justification: Severely Fragmented: All known plants of *Zieria odorifera* subsp. *warrabahensis* occur in a single population spread across only a few hectares. The population size of this species is very low (only 100 mature individuals), and the species is found growing in heath and *Eucalyptus prava*/*Callitris endlicheri* layered woodland on granite outcrops (Duretto and Forster 2008; PlantNET 2018; L. Copeland *in litt*. May 2016, November 2016, January 2017). According to Copeland (2017), the search for this species and other rare plants in the broader area has failed to find any further sites of *Zieria odorifera* subsp. *warrabahensis*. The species is likely to have low dispersal capacity (by ants) (as per other *Zieria* spp., Westboy *et al*. 1990, Auld 2001) and limited suitable habitat. The small size of the known population makes it uncertain if it is viable. Therefore, this species is considered to be severely fragmented.

Location: *Zieria odorifera* subsp. *warrabahensis* occurs at one location, as defined by the most plausible threat, which is grazing by herbivores (goats and sheep). Copeland (pers. comm. 2017) has found a number of plants browsed with leaves chewed off and some reduced to broken stems in both Warrabah National Park and adjacent private land. The area where the species occurs is known to have a high concentration of goats, and the private property is subject to regular sheep grazing. Grazing represents a high risk for this species across the whole range given its very highly restricted distribution and its very small population size of only 100 plants.

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: sub criterion met for iii) and v).

Justification: Continuing decline is inferred in the following;

(iii) quality of habitat: Habitat quality is declining with ongoing adverse grazing pressure (Copeland pers. comm. 2017). Feral goats can cause significant habitat degradation by removing or destroying vegetation, trampling, decreasing soil stability and contributing to erosion (NSW Scientific Committee 2004).

(v) number of mature individuals: Only 100 mature individuals of *Zieria odorifera* subsp. *warrabahensis* are known to occur in a single population at Warrabah NP. This species is sensitive to grazing which can prevent regeneration of plants (Copeland pers. comm. 2017). Copeland (pers. comm. 2017) has observed several plants damaged by browsers, for example, with leaves chewed off and some plants reduced to broken stems with barely any leaves remaining. The area where the subspecies occurs is known to have a high concentration of feral goats and many goat scats, suggesting ongoing goat activity (Copeland pers. comm. 2017). The ongoing pressure from feral goats and sheep is leading to a continuing decline in the numbers of plants of this species.

c) Extreme fluctuations.

Assessment outcome: sub criterion data deficient

Justification: There is no data on extreme fluctuations in the species abundance or distribution (Copeland pers. comm. 2017).

Criterion C Small population size and decline

Assessment Outcome: Critically Endangered under Criterion C2a(ii)

Justification: A species with less than 250 mature individuals, would be considered to meet the threshold for the category of Critically Endangered. According to last census data (2007), the population size of this species is only 100 mature individuals, and all individuals are in a single population across few hectares.

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

1) An observed, estimated or projected continuing decline of at least 10, 20 or 25% in 10, 5 or 3 years or 3, 2 or 1 generations, respectively (up to a max. of 100 years in future).

Assessment outcome: sub criterion data deficient

Justification: The population size of this species is very low. The census data available is very limited, and there is no evidence to determine whether or not there has been a reduction of this species. There is insufficient data in regards population size trend and generation length to assess this species under this criterion.

2) An observed, estimated, projected or inferred continuing decline

Assessment outcome: sub criterion met

Justification: A continuing decline is inferred in the number of mature individuals of *Zieria odorifera* subsp. *warrabahensis.* There are only 100 plants occurring in a single population at Warrabah NP. The area where the subspecies occurs is known to have a high concentration of feral goats and many goat scats, suggesting ongoing goat activity.

Damage to *Z. odorifera* subsp. *warrabahensis* plants by goats has been recorded (Copeland pers. comm. 2017). The ongoing pressure from feral goats and sheep is leading to a continuing decline in the numbers of plants of this species.
In addition, at least 1 of the following 3 conditions:

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

Assessment outcome: sub criterion met at endangered threshold
Justification: A species with less than 250 mature individuals in each population, qualifies for the Endangered threshold. The population size of this species is 100 mature individuals in a single population.

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

Assessment outcome: sub criterion met at critically endangered threshold
Justification: A species with 90-100% of mature individuals in a single population, qualifies for the Critically Endangered threshold. For this species, 100% of all known individuals are in a single population.

b. Extreme fluctuations in the number of mature individuals

Assessment outcome: sub criterion data deficient
Justification: There is no data on extreme fluctuations in the species abundance or distribution (Copeland pers. comm. 2017).

Criterion D Very small or restricted population
Assessment Outcome: Endangered under Criterion D
Justification: *Zieria odorifera* subsp. *warrabahensis* is known from a single population of only 100 mature individuals in Warrabah National Park, northern NSW (Copeland pers. comm. 2017). A species with less than 250 mature individuals qualifies for the Endangered threshold for Criterion D.

Criterion E Quantitative Analysis
Assessment Outcome: Data Deficient
Justification: At present, there is no sufficient data available for *Zieria odorifera* subsp. *warrabahensis* to estimate the risk of extinction under this criterion.

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.

Habitat loss, disturbance and modification

- Control feral goats and sheep to prevent modification or disturbance the habitat of this species.

Invasive species

- Control feral goat populations to eliminate browsing and trampling impacts on this species and its habitat.
- Fence the area where the population is located to protect it from feral goats and sheep.
- Maintain any reserve fencing to minimise movement of goats into the national park.

Ex situ conservation

- Develop a targeted seed collection program from ex situ seed banking.
- Determine the level of genetic diversity and inbreeding.
- Assess the need for population enhancement and the establishment of new populations.

Stakeholder Management

- Develop and implement a stock management plan.
- Manage known sites to ensure appropriate sheep grazing regimes occur to allow recruitment from seedlings or to exclude grazing from where plants are known.
- Liaise with neighbours of the National Park to reduce likelihood of sheep and goats entering the National Park and impacting on *Zieria odorifera* subsp. *warrabahensis*.

Survey and Monitoring priorities

- Monitor the species' abundance, survival, growth and recruitment over time.
- Monitor the impact of feral goats and domestic animals (sheep) on this species.
- Monitor for increased habitat degradation.
- Monitor the species during extreme weather, especially drought.
- Regular surveys to determine whether there is a decline in the population.
- Further survey of any other potential habitat.
- Monitor occurrence of fire in and around the known habitat of the species and the response of the species to any fires.

Information and Research priorities

- Information and research about the species ecology:
    - Primary and secondary juvenile periods
    - mode of dispersal,
    - recruitment,
    - persistence and lifespan of soil seed banks,
- fire ecology and appropriate fire regime:
    - response to fire
    - time to fire resistance for the species
    - resilience to frequent fire
    - germination after fire
    - seedling survival after fire
    - ability to recruit independent of fire
- Research best protocol for translocation

References

Armstrong JA (1979) Biotic pollination mechanisms in the Australian flora – a review. *New Zealand Journal of Botany* **17**, 467-508.

Armstrong JA (2002) *Zieria* (Rutaceae): a systematic and evolutionary study. *Australian Systematic Botany* **15**, 277-463.

Auld TD (2001) The ecology of the Rutaceae in the Sydney region of south-eastern Australia: Poorly known ecology of a neglected family. *Cunninghamia* **7**, 213-239.

Clarke PJ, Knox KJE, Campbell ML, Copeland LM (2009) Post-fire recovery of woody plants in the New England Tableland Bioregion. *Cunninghamia* **11**, 221-239.

Duretto MF, Forster PI (2008) New subspecies for *Zieria odorifera* J.A. Armstr. (Rutaceae) from northern New South Wales. *Austrobaileya* **7**, 681-690.

IUCN Standards and Petitions Subcommittee (2017) Guidelines for Using the IUCN Red List Categories and Criteria, Version 13.

NSW NPWS (2003) Warrabah National Park Plan of Management. Department of Environment and Conservation (NSW).

NSW Scientific Committee (2004) Competition and habitat degradation by Feral Goats, *Capra hircus* Linnaeus 1758 - key threatening process listing. http://www.environment.nsw.gov.au/determinations/FeralGoatsKtp.htm (accessed 2.11.17).

NSW Scientific Committee (2018) Preliminary Determination to list the shrub *Zieria odorifera* subsp. *warrabahensis* Duretto and P.I.Forst as a Critically Endangered Species.

PlantNET (2018)(The NSW Plant Information Network System) Royal Botanic Gardens and Domain Trust, Sydney. http://plantnet.rbgsyd.nsw.gov.au/cgi-bin/NSWfl.pl?page=nswfl&lvl=in&name=Zieria~odorifera+subsp.~warrabahensis (accessed 2nd August 2018).

Westoby M, Rice B, Howell J (1990) Seed size and plant growth frim as factors in dispersal spectra. *Ecology* **71**, 1307-1315.

Expert Communications

Copeland, Lachlan. Senior Botanist, Eco Logical Australia. Email: Lachlanc@ecoaus.com.au