

## Conservation Assessment of *Zieria buxijugum*

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### *Zieria buxijugum* J. Briggs & J. Armstrong (Rutaceae)

Distribution: Endemic to NSW

Current EPBC Act Status: Endangered

Current NSW BC Act Status: Critically Endangered

Proposed change for alignment: List on EPBC Act as Critically Endangered

### Conservation Advice: *Zieria buxijugum*

### Summary of Conservation Assessment

*Zieria buxijugum* is found to be eligible for listing as Critically Endangered under Criteria B1ab(iii)+2ab(iii); C2a(ii).

The main reasons the species is eligible for listing in the Critically Endangered category are: i) a very highly-restricted distribution, the area of occupancy (AOO) was estimated to be 4 km<sup>2</sup>, measured with a 2 x 2 km grid as per IUCN Guidelines (IUCN 2017), while the extent of occurrence (EOO) was also found to be 4 km<sup>2</sup> as IUCN (2017) stipulates that EOO cannot be less than AOO. Both AOO and EOO meet the distribution thresholds for Critically Endangered (<10 km<sup>2</sup> and <100 km<sup>2</sup>, respectively); ii) there are less than 100 mature individuals in a single remaining location; iii) Continuing decline is projected in quality of habitat and without ongoing management in the number of mature individuals. There is also a high probability of extinction due to a stochastic event. Past fluctuations in population size demonstrate the potential for rapid decrease and highlight the potential for reduced genetic variation in the recovering population. In addition, recovery and survival of the species appears to be dependent on continued active management. These factors leave *Zieria buxijugum* extremely vulnerable to chance events, a single such event could lead to the extinction of the species; and iv) all mature individuals occur in one population.

### Description and Taxonomy

According to the NSW Scientific Committee (2009), "*Zieria buxijugum* was first discovered in 1986. The species has been known by a number of informal names, including '*Z. buxijugum* J. D. Briggs & J. A. Armstr. ms (Parris 9079)' (Armstrong, 2002), '*Z. sp. G*' (Armstrong, 1991), '*Z. sp. 14*' (Briggs and Leigh, 1990) and '*Z. sp. P* (Box Range North)' (J.D. Briggs pers. comm. 2008). *Zieria buxijugum* is closely related to *Z. formosa*, from which it is distinguished by the absence of small terminal appendages on its anthers and narrower leaflets (2-3 mm wide cf. 3-5 mm wide in *Z. formosa*)."

The species was formally described by Armstrong (2002) as an "Erect shrub up to 3.5 m; young branches terete, densely tuberculate and covered with a velvety indumentum of short stellate hairs throughout; older branches less conspicuously tuberculate, glabrescent. Leaves palmately trifoliolate, opposite, petiolate. Petiole 2.0–5.0 mm long, tuberculate, pubescent all over with a dense velvety indumentum of very short stellate hairs. Central leaflet linear to narrow oblanceolate (7.0) 15.0–28.0 (41.0) × (1.5) 2.0–3.0 (4.0) mm, dull grey-green above, pale green below; upper surface tuberculate, with a fine velvety indumentum of very short stellate hairs, midrib conspicuously sunken, lateral veins slightly sunken; under surface tuberculate, with a dense velvety indumentation of short stellate hairs; apex obtuse; margin entire, recurved; primary vein prominent on under surface, densely stellate-pubescent, with numerous tubercles; secondary venation slightly

raised but largely obscured on under surface. Secondary leaflets similar to central leaflet but smaller, usually 0.6–0.8 times as long. Inflorescence an axillary cyme, as long as or longer than the leaves (2) 10–16 (28)-flowered. Peduncle (3) 4–10 mm (15) long, densely tuberculate, densely pubescent with short stellate hairs. Bracts persistent (2 bracts are present on the peduncles of juvenile inflorescences, only 1 bract or bracteole is present at each node in mature inflorescences), linear to oblanceolate, 1.0–5.0 × 0.5–1.0 mm, sparsely tuberculate. Pedicel terete, 1.0–1.5 mm long, not tuberculate, densely stellate hairy, subtended at the base by a pair of minute bracts. Flowers white, moderately conspicuous, 6.0–7.0 mm diameter. Calyx lobes deltoid, 0.8–1.0 × 0.6–0.8 mm, very much shorter than the petals, tuberculate, hirsute adaxially, densely pubescent abaxially with very short stellate hairs. Petals imbricate in bud, ovate-elliptic to broad oblanceolate, 3.5–4.0 × 1.5–2.0 mm, with a very small inflexed acuminate tip; adaxial surface moderately to sparsely stellate-pubescent; abaxial surface tuberculate, densely stellate-pubescent. Stamens not persisting in the fruiting stage; filaments 0.8–1.0 mm long, glabrous, not tuberculate; anthers 0.4 × 0.4 mm, not apiculate, attached in the lower third, orange-red in colour (cream in dry state). Disc interrupted and distinct, glabrous, white. Ovary dotted with pellucid oil glands, glabrescent. Stigma 0.3 mm broad, 4-lobed. Fruit red-brown when young, becoming green-brown to green at maturity, densely tuberculate (i.e. glands obvious on carpel surface), with sparsely scattered stellate hairs when young, becoming glabrescent at maturity. Cocci lacking an appendage. Seed dark brown to dark grey-brown, striate, 1.8–2.0 × 1.0–1.3 mm; covering to the raphe shiny black and striate, not smooth. Seed surface: ridges well-developed but flattened; branches and cross-ridges not common; wax absent. Elaiosome 2.0 × 0.8 mm.”

A systematic study by Morton (2015) combined molecular and morphological data to study species-level relationships within *Zieria*. This study found a close relationship between *Zieria buxijugum*, *Z. formosa*, *Z. parrisiae*, *Z. tuberculata*, and *Z. granulata*. Morton (2015) states that “the clade contains eight species, one species being *Z. buxijugum* (BPP 100 and BS 93%), and although the species all occurred mostly in the southeastern territory (New South Wales, Victoria and Tasmania), they had numerous bp changes between taxa.” This indicates that there are measureable genetic differences between all of these species, making it likely that *Zieria buxijugum* will be maintained as a distinct species in the future.

### **Distribution and Abundance**

The NSW Scientific Committee (2009) state that “*Zieria buxijugum* is endemic to New South Wales and known only from the Pambula area on the far south coast of NSW.”

“*Zieria buxijugum* has a very highly restricted geographic distribution. The species is known from only one locality within a total extent of occurrence and area of occupancy of less than 4 km<sup>2</sup>, based on 2 x 2 km grid cells, the scale recommended for assessing areas of occupancy by IUCN (2008). Other surveys and searches in and around the area failed to locate any additional populations (Briggs and Leigh, 1990; NPWS 2002, J.D. Briggs pers. comm. 2008)” (NSW SC 2009).

At the time of discovery in 1986, 68 plants over 1 m in height were recorded, but no data was collected on how many smaller plants and seedlings were present (NPWS 2002, J.D. Briggs pers. comm. 2017). The population was monitored in 1999 and 121 plants > 1 m were recorded (NPWS 2002).

*Zieria buxijugum* suffered severe browsing by swamp wallabies over the period from 1999-2002. There is some uncertainty about the population minimum reached during this period, due to the use of height classifications as a proxy for adult status. In 2001, Briggs and Wright recorded 32 plants > 1 m and 64 plants 0.5 – 1 m (96 plants > 0.5 m), with a total of 305 plants across all size classes (NPWS 2002). There were apparently further reductions over 2002, with low numbers of mature plants reported by both the NSW Scientific Committee (6 plants > 1 m; 2009) and NPWS (21 plants > 0.5 m; J. Briggs pers. comm. 2017). Although the number of large plants became very low, many of the individuals did not actually die; instead they were browsed to a very low stature (J. Briggs, pers. comm. 2017).

To reduce browsing, 11 wire-mesh guards were constructed around selected plants in 2001 and another ten installed in 2002, protecting a total of 36 plants. (J. Briggs, pers. comm. 2017). These guards proved highly effective against wallabies, and of the 36 plants guarded by 2002, 33 were alive in 2012 (J. Briggs, pers. comm. 2017).

The population was not monitored between 2002 and 2012, due to a lack of resources (J. Briggs pers. comm. 2017). Monitoring was resumed in 2012 and, as of 2017, continues under the NSW Saving our Species program. Results of the monitoring program are shown in Figure 1. Slight year-to-year declines record the loss of height due to tip dieback rather than death (J. Briggs pers. comm. 2017). The community was last surveyed in May 2017. A total of 135 plants were recorded within the guards, and an additional 10-20 unprotected plants were noted. Of all plants seen, 98 were individuals > 0.5 m (J.D. Briggs pers. comm. 2017).

Three genotypes of *Zieria buxijugum* are in cultivation at the National Botanical Gardens, Canberra, with seed collections from 61 maternal lines (T. North, pers. comm. 2017; D. Taylor, pers. comm. 2017). One genotype is in cultivation at the Mount Annan Botanical Gardens, and 500 seeds are preserved in the Mount Annan seed bank (B. Lyte, pers. comm. 2017), which represent a composite collection from 25 plants (G. Errington, pers. comm. 2017). *Zieria buxijugum* is not represented at the Booderee Botanical Garden (S. Pederson, pers. comm. 2017).

## Ecology

The NSW Scientific Committee (2009) state that “This species occurs in shrubby heath vegetation growing in skeletal brown loam, on an ignimbrite rock outcrop. Plants flower in September and are likely to be pollinated by insects. The fire response of *Zieria buxijugum* is unknown, however many species of *Zieria* are killed by fire.”

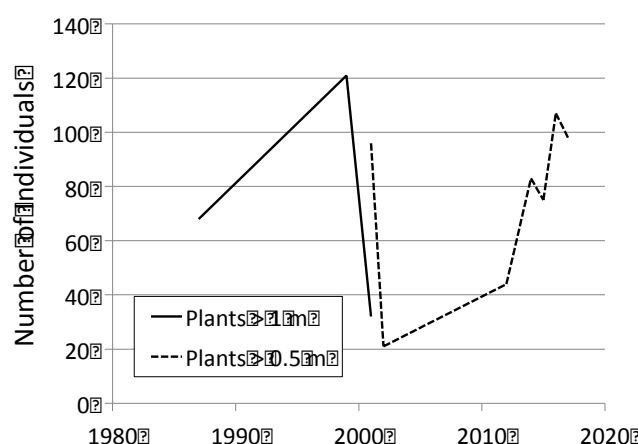


Figure 1 – Number of plants in different size classes between 1987 and 2017. Data from NPWS 2002 and J. Briggs, pers. comm. 2017

Regarding the fire ecology of *Zieria buxijugum*, it has been observed resprouting from the base after drought, and shoots may develop from exposed roots (J. Briggs, pers. comm. 2017). This suggests it may not be an obligate seeder, but further observations are needed.

The EPBC conservation advice (EPBC TSSC 2016) states “Box Range *zieria* [*sic*] grows in full sun to partial shade and flowers prolifically in September. Flowers are almost certainly insect pollinated, followed by high levels of fruiting. The species withstands harsh climatic conditions with extremely hot

and dry summers, though the driest conditions at the site normally occur in winter. There is little competition from other species as there is much exposed rock at the site and few herbaceous species present. Individuals have not been regularly monitored in the field, though it is suspected that this species may live 20 - 30 years.”

Co-occurring plants include *Melaleuca armillaris* (Bracelet Honey-myrtle), *Cassinia longifolia* (Shiny Cassinia), *Plectranthus parviflorus* (Cockspur Flower), *Olearia iodochoa* (Violet Daisy-bush), *Platysace lanceolata* (Shrubby Platysace) and *Dendrobium speciosum* (Rock Lily) (Briggs and Leigh, 1990).

Multiple sources agree that the species is a food source for swamp wallabies (NSW NPWS 2002; NSW Scientific Committee, 2009; Briggs 2015; EPBC TSSC 2016). Wallaby numbers are believed to have increased due to land clearing since European settlement, which increased access to pasture. Wallaby browsing pressure was observed to increase following an El Niño-driven drought event in 2001-2002 (NSW NPWS 2002; Briggs, 2015).

### Threats

The NSW Scientific Committee (2009) state that “The main threat to this species is severe browsing from swamp wallabies. Wallabies are known to inhabit the bushland where this species exists and feed on the nearby pasture at night (Armstrong, 2002). Wallabies were apparently not a significant threat until the winter 2000 when drought resulted in an increased browsing pressure. The local population of wallabies is likely to have increased as a result of the surrounding area being cleared and pasture established (NSW NPWS 2002). Plants over 2 m tall are less vulnerable to heavy browsing than smaller plants (NSW NPWS 2002).”

“The small population size and restricted area exposes this species to very high risks of extinction through events such as wildfire, and severe drought.”

“In April 2001 NPWS installed 10 wire mesh guards around selected *Z. buxijugum* plants to protect them from browsing by wallabies. The plants chosen for protection were scattered across the site, with the aim of ensuring a source of seed-producing plants would remain across the site in case there are further severe browsing events. If further severe browsing does occur, then it is expected that protection of some large seed-producing plants will assist future seedling recruitment and population recovery.”

The entire site was fenced to prevent browsing in 2017, using funding from the NSW Saving our Species program. It is believed that this will allow the recruitment of additional plants beyond those individuals specifically protected with browsing guards (J. Briggs, pers. comm. 2017).

The EPBC conservation advice (EPBC TSSC 2016) identified three further threat categories: 1) site disturbance: due the fact that this species occurs in a single, small area, there is the potential for the entire population to be destroyed by a single random event; 2) private land tenure: although the current land owners are supportive of recovery efforts, sale of the land or changed use could result in new threats; 3) fire: many *Zieria* species are vulnerable to fire, and the effect of fire on *Zieria buxijugum* is unknown. Conversely, the recovery plan for *Zieria buxijugum* states “Fires of low to moderate intensity are unlikely to impact on the entire population, as the site is very rocky and unlikely to carry a fire across the whole of the habitat” (NSW NPWS 2002). In addition, the site “is a rocky outcrop on top of a steep hill” which “appears to be a fire refugia and probably would only burn in catastrophic fire conditions” (J. Briggs, pers. comm. 2017).

*Zieria buxijugum* appears to be sensitive to cycles of drought. The reduction in population from 1999 to 2002 can be traced to a drought event in 2000-2002, linked to the El Niño Southern Oscillation. This drought reduced food sources for swamp wallabies, increasing browsing pressure on *Zieria buxijugum* with the effect that the number of plants > 1 m high decreased by at least 82% and possibly up to 95%. El Niño events are well-known to affect Australia and occur at multi-year scales. While the current observation window is relatively short (31 years, slightly more than one generation) it is assumed that these cycles have affected the ecosystem around *Zieria buxijugum* throughout its evolution and will continue to affect it in the future.

#### Assessment against IUCN Red List criteria

For this assessment it is considered that the survey of *Zieria buxijugum* 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 under Criterion A the species must have experienced a population reduction of at least  $\geq 30\%$  (Vulnerable threshold) over three generations or 10 years (whichever is longer). Generation time for *Zieria buxijugum* is believed to be 20-30 years, so the required window would be 60 to 90 years. During the period from 1986 to 2017 (31 years), observations suggests that *Zieria buxijugum* has experienced a slight net increase in abundance. However, due to differing thresholds for 'adult' status (> 1 m vs. > 0.5 m), numbers from these years cannot be directly compared. In the middle of this period, *Zieria buxijugum* suffered a severe browsing event, which reduced the number of large plants by of 82-95%. However, many of these plants survived and subsequently regrew. These fluctuations make projections of the overall trend in population size unreliable. A longer period of observation is required to understand whether there is a net trend towards increase or reduction in *Zieria buxijugum*, and whether current safeguards are sufficient to ensure an increasing population.

##### *Criterion B Geographic range*

Assessment Outcome: Critically Endangered under Criterion B via B1ab(iii)+2ab(iii).

Justification: *Zieria buxijugum* occurs at only a single site, with one population and one location.

Extent of Occurrence: The NSW Scientific Committee (2009) estimated both the extent of occurrence (EOO) for *Zieria buxijugum* and the area of occupancy (AOO) to be 4 km<sup>2</sup> (EOO is reported as equal to AOO, despite the range of the species measured with minimum convex hull polygon being less than AOO, to ensure consistency with the definition of AOO as an area within EOO, following IUCN Guidelines 2017). To be listed as Critically Endangered under Criterion B1 a species must have an EOO of <100 km<sup>2</sup>. *Zieria buxijugum* meets the EOO threshold for Critically Endangered under Criterion B1.

Area of Occupancy: The NSW Scientific Committee (2009) estimated the area of occupancy (AOO) for *Zieria buxijugum* to be 4 km<sup>2</sup>, as it occupies a single 2 x 2 km cell, the scale of measurement recommended by IUCN Guidelines (2017). This estimate remains valid as no further sites are known. To be listed as Critically Endangered under Criterion B2 a species must have an AOO of <10 km<sup>2</sup>. *Zieria buxijugum* meets the AOO threshold for Critically Endangered under Criterion B2.

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 = 1 (CR),  $\leq 5$  (EN) or  $\leq 10$  (VU).

Assessment Outcome: Subcriterion met at Critically Endangered threshold.

Justification: *Zieria buxijugum* is found at only one location, an exposed rocky slope. Targeted searches by trained botanists in similar habitat have failed to locate any further populations. Browsing by native herbivores at this location is known to be a serious threat. In addition, this single location occurs on private land. The species' recovery is dependent on continued cooperation of the landholders.

- 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: Subcriterion met for (iii) Continuing decline projected in quality of habitat; and (v) number of mature individuals.

Justification: The very small population size, extent of occurrence, and area of occupancy of *Zieria buxijugum* make it susceptible to stochastic events. Browsing by wallabies currently represents a major threat. *Zieria buxijugum* is protected from browsing by wire mesh guards and a fence. While these have been effective in protecting individuals and increasing population numbers, there is a high potential for these protections to be damaged or circumvented; without maintenance these outcomes are extremely likely. The ability to install and maintain these safeguards is entirely dependent on continued cooperation from the landholders. Potential changes in land ownership add to the uncertainty in protecting this habitat.

Browsing pressure is known to have increased in response to the 2000-2002 drought. The severity of drought events is expected to increase with changing climates in the future. In addition to the known browsing pressures, stochastic events such as fire, storms, or landslips could have a severe impact on the quality of habitat and mature individuals at this small site.

- c) Extreme fluctuations.

Assessment Outcome: Data deficient.

Justification: During the 31 years (slightly more than one generation) that *Zieria buxijugum* has been under observation, there has been a large decrease and subsequent increase in the number of large plants due to browsing, but many of the plants remained alive (albeit at a smaller stature). There is not sufficient data on actual population fluctuations (as opposed to changes in plant size) to assess extreme fluctuations in this species. However, the species should be watched carefully for further signs of fluctuations, particularly during El Niño-related drought events, which affect Australia on a cyclical basis.

#### *Criterion C Small population size and decline*

Assessment Outcome: Critically Endangered under Criterion C via C2a(ii).

Justification: The current population of *Zieria buxijugum* consists of 98 mature individuals. The threshold for listing as Critically Endangered under Criterion C is less than 250 individuals. *Zieria buxijugum* meets this threshold.

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 (up to a max. of 100 years in future).

Assessment Outcome: Data Deficient.

Justification: There is insufficient data to assess *Zieria buxijugum* against this criterion. 30 years of observation have shown an overall increase in the number of individuals (from 68 to 98), combined with dramatic changes in plant size due to grazing impacts. Data on individual plant survival are not available to adequately assess population change.

C2. An observed, estimated, projected or inferred continuing decline

Assessment Outcome: Criterion met.

Justification: Over 31 years (1 to 1.5 generations) of observation, this small population experienced an extreme reduction in large, seed-producing plants, followed by a recovery due to active management. The potential for rapid decrease, contrasted with the current increasing trajectory, makes it difficult to predict whether the species will increase or decrease in the future. However, several factors expose *Zieria buxijugum* to increased risk, leading to the probability of declines in the future. The small population size, concentrated in a single location, leaves the species vulnerable to stochastic events, such as wildfire, severe storms, or changes in land use. Reduced genetic variability as the result of a population bottleneck also increases the risk that all individuals in the population will be equally vulnerable to an adverse stochastic event, such as a heatwave, drought, pathogen outbreak, or insect attack. In addition, there is continued browsing pressure from wallabies, with mortality observed in unguarded individuals during the first ten years of the recovery program. Together, these factors indicate that without continued intervention, the *Zieria buxijugum* population would decline.

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

- a (i). Number of mature individuals in each population  $\leq 50$  (CR),  $\leq 250$  (EN) or  $\leq 1000$  (VU).

Assessment Outcome: Subcriterion met at Endangered threshold.

Justification: There are 98 adult individuals of *Zieria buxijugum*. This meets the threshold for listing as Endangered under Criterion C2a(i).

- a (ii). % of mature individuals in one population = 90-100% (CR), 95-100% (EN), 100% (VU).

Assessment Outcome: Criterion met at Critically Endangered threshold.

Justification: There is only a single known population of *Zieria buxijugum*. 100% of all mature individuals occur in this population. This meets the threshold for listing as Critically Endangered under Criterion C2a(ii).

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data deficient.

Justification: During the 31 years (slightly more than one generation) that *Zieria buxijugum* has been under observation, there has been a large decrease and subsequent increase in the number of large plants due to browsing, but many of the plants remained alive (albeit at a smaller stature). There is not sufficient data on actual population fluctuations (as opposed to changes in plant size) to assess extreme fluctuations in this species. However, the species should be watched carefully for further signs of fluctuations, particularly during El Niño-related drought events, which affect Australia on a cyclical basis.

*Criterion D Very small or restricted population*

Assessment Outcome: Endangered under Criterion D.

Justification: There are 98-107 likely mature individuals of *Zieria buxijugum* (98 > 1 m recorded in 2017; 107 recorded in 2016, with losses attributed to tip die back only, J. Briggs pers. comm. 2017.) To be listed as Endangered under Criterion D a species must have <250 mature individuals. *Zieria buxijugum* meets the threshold for listing as Endangered under Criterion D.

*Criterion E Quantitative Analysis*

Assessment Outcome: Data Deficient.

Justification: No quantitative analysis of the probability of extinction has been undertaken.

## **Conservation and Management Actions**

There is a NSW Saving Our Species site-managed program for *Zieria buxijugum* (NSW OEH 2017), an EPBC Conservation Advice (EPBC TSSC 2016), and a national recovery plan (NSW NPWS 2002). The following actions are derived from these documents:

### Habitat loss, disturbance and modification

- Browsing by native herbivores represents the most severe risk to *Zieria buxijugum* at this time. Browsing exclusion guards have been in place on individual plants since 2001 (NSW NPWS 2002) and the number of guarded plants increased between 2001 and 2017. A macropod-proof fence was installed around the entire site in 2017. Maintaining these established protections is central to actively managing the recovery of this species (NSW OEH 2017).
- Monitoring for disturbance is in place to track the recovery of *Zieria buxijugum* and ensure that current fencing provides adequate protection from native herbivores (NSW OEH 2017).
- Flora monitoring is being used to track species abundance and condition over time, to ensure that other threats to the species do not go unnoticed (NSW OEH 2017).
- Monitoring of habitat quality is also being undertaken (NSW OEH 2017).
- *Zieria buxijugum* occurs exclusively on private land. Habitat monitoring provides a means to assess whether actual management of the site accords with negotiated agreements.

### Ex situ conservation

- Seedbanking is being used to maintain a supply of genetic material, which may be used to supplement the population in the future (NSW OEH 2017). Seeds from 61 maternal lines are represented at the National Botanical Gardens, and a total of 500 seeds from 25 plants are represented at the Mount Annan Seed Bank. Additional collections should be made as necessary to maintain and enhance this ex situ seed bank.
- Living specimens of *Zieria buxijugum* are maintained at the National Botanical Garden (ACT), with three genotypes, and the Mount Annan Botanical Garden (NSW), with two specimens of one genotype. Cultivation of further genotypes is recommended, with the goal of providing a sufficient base to supplement the existing wild population in the case of a decline.

### Stakeholder Management

- The only population of *Zieria buxijugum* occurs on private land. Uncertainty of future land management practices also represents a significant threat to the continued survival of the species. The landowners have been reported to be supportive of actively managing the species (NSW NPWS 2002). Land manager negotiations are being undertaken to ensure that land management is sympathetic to the long term requirements of the species (NSW OEH 2017). Maintaining a positive relationship with the landowners is of great importance to the survival of this species.
- The NSW Saving Our Species program has provided monetary support for the construction of a macropod-proof fence (NSW OEH 2017). Continuing to ensure that landowners are aware of financial support for species management measures may help them continue a supportive attitude.
- Continued monitoring of the site helps to build an ongoing relationship with land managers and provides a means to assess whether land use conditions change (NSW OEH 2017).



### Survey and Monitoring priorities

- A review of past monitoring data is suggested, in order to better understand past reductions in population size.
- Future monitoring needs to account for individual plant survival and growth and any recruitment of new individuals or loss of existing individuals. For example, the reduction of mature plants over 1 m in height into height classes under 1 m should be distinguished from the death of plants over 1 m.
- Monitoring should be conducted annually to:
  - Determine if wallabies and other herbivores have been excluded from the entire site and record any disturbance due to browsing (NSW OEH 2017).
  - Track species abundance (including survival and recruitment) and condition over time (NSW OEH 2017).
  - Monitor the condition of the habitat and ensure that land management remains sympathetic to the long term requirements of the species (NSW OEH 2017).

### Information and Research priorities

- To understand the ecology of *Zieria buxijugum*
  - Seed biology – germination and dormancy mechanisms, seed viability and longevity, seed dispersal and predation.
  - Recruitment and establishment – survival rates of seedlings, time to first flowering, does fruiting vary with adult plant size, causes of mortality, population modelling (e.g., impact of seedling loss), growth and development rates.
  - Fire response. Is *Zieria buxijugum* an obligate seeder, or can it resprout after fire? At what rate does the seedbank accumulate? What are the rates of seedling/juvenile and adult survival following fire? What fire regimes can likely be tolerated by the species?
- To understand the habitat of *Zieria buxijugum*
  - Why did wallaby browsing increase sharply in 2000-2001, greatly reducing the number of large individuals? Did the expansion of nearby pastures or reduction of other species in the area contribute to browsing pressure for *Zieria buxijugum*? Can future fluctuations in population size be expected to occur, particularly in response to cycles of drought?
- To understand the potential for establishing additional ex-situ populations
  - How has the species fared under cultivation at the National Botanical Garden and Mount Annan Botanical Garden?
  - Is there nearby habitat, particularly on reserved or protected land, where an additional population might be established?
  - Can the extent of the existing population be successfully expanded across adjoining unoccupied potential habitat that is now within the fenced rhyolite outcrop?

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### Expert Communications

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