Conservation Assessment of *Homoranthus croftianus* J.T.Hunter (Myrtaceae)

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***Homoranthus croftianus* J.T.Hunter (Myrtaceae)**
Distribution: Endemic to NSW
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act: Critically Endangered

Reason for change: non-genuine change based on increased knowledge of species abundance, distribution and threats acting on the population.

Summary of Conservation Assessment

Homoranthus croftianus was found to be eligible for listing as Critically Endangered under Criterion B1(a)(b iii v) and B2(a)(b iii v).

The main reasons for this species being eligible are (i) *Homoranthus croftianus* has a highly restricted Extent of Occurrence (EOO) and Area of Occupancy (AOO) of 4 km^2; (ii) *H. croftianus* is known from a single threat-defined location; and (iii) continuing decline has been observed and is projected to continue in the area, extent and quality of habitat, and number of mature individuals due to the combined effects of increased frequency and duration of drought due to climate change, adverse fire regimes, and browsing by feral and native herbivores.

Description and Taxonomy

Homoranthus croftianus (Bolivia Homoranthus) is a conventionally accepted species (CHAH 2022), described by Hunter (1998) as an "erect shrub to 2 m tall by 1.5 m wide. Stems yellow to orange when young, turning brown with age. Leaves opposite, decussate, 2.5–8 mm long, 0.4–0.7 mm wide, 0.6–0.9 mm thick; blade incurved or rarely straight or recurved, linear, in transverse section subobtriangular, abaxially flat or concave, dark green to pale green; apex curved or straight, acuminate to cuspidate; petiole 0.1–0.5 mm long. Flowers solitary in axils on undifferentiated branchlets, greenish to cream. Peduncles 0.7–1.4 mm long, crowned between bracteoles, bracteoles caducous, gland dotted, 3.5–4.5 mm long, red-brown. Hypanthium 5-costate, with multicellular trichomes between the rounded costae on the ovary region, 1.5–3 mm long, 1–1.5 mm wide. Sepals 2–3 mm long, 0.3–0.6 mm wide, margins variously divided on individual flowers from undivided to 3-laciniate, gland-dotted. Petals orbicular to widely ovate, 1–1.2 mm long, 1–1.4 mm wide, margins entire. Stamens 10; filaments 0.1–0.3 mm long; anthers 0.3–0.5 mm long; staminodes 20, free, 0.3–0.5 mm long. Style 1.5–2.5 mm long, swollen basally, with long trichomes on the top third; stigma papillate. Fruit simple, dry indehiscent nut, 3.5–4 mm long, 1.2–1.5 mm wide, caducous after seed set, orange brown."

Figure 1 - Homoranthus croftianus flowers. Image: Gavin Phillips

Homoranthus croftianus has no known synonyms (CHAH 2022). It is morphologically similar to two other narrow-range endemic *Homoranthus* from the New England Tableland, *H. bruhlii* and *H. elusus,* but is distinguished from both by the presence of long, unicellular trichomes between the ribs on the flower hypanthium (Copeland *et al.* 2011) and the ranges of all three do not overlap.

Distribution and Abundance

Homoranthus croftianus is a naturally rare species (*sensu* Harrison *et al.* 2008) endemic to the Bolivia Hill Range south of Tenterfield in northern NSW. This area lies within the New England Tablelands Bioregion (Department of Agriculture, Water and Environment 2012) on the traditional lands of the Ngarabul First Nations people (Horton 1996; NPWS 2011).

Homoranthus croftianus is restricted to a small area of the Bolivia Hill Range, particularly growing in exposed situations on and around granite outcrops up to approximately 1200 m elevation (Hunter 1998; Copeland *et al.* 2011; T. Soderquist *in litt.* January 2023). The species was first recorded in 1997 during the assessment of Bolivia Hill prior to acquisition by the National Parks and Wildlife Service (Hunter 1998). This resulted in the gazettal of Bolivia Hill Nature Reserve in 2000 due to the presence of *H. croftianus* and high concentrations of other rare endemic plant species (NPWS 2011). Currently, all known stands of *H. croftianus* occur within this reserve (Copeland *et al.* 2011).

Early surveys of this species noted that the total *Homoranthus croftianus* population was likely less than 500 plants, scattered within a radius of only a few kilometres (Hunter 1998, 2002). In recent years, further surveys have located more stands and increased the known abundance (OEH 2020), though some previously recorded stands on the southwest limit of the population appear to be no longer extant and cannot be relocated (T. Soderquist pers. comm. August 2022). Thus, the species remains highly localised geographically, with all known plants occurring in an area of approximately 26 ha (DPE 2022a). Currently, the population is considered to consist of five discrete stands within this small area (DPE 2022a), which are separated by areas of largely unvegetated granite slabs that can be several hundred metres across (G. Phillips pers. obs. January 2021). Given these distances are less than the foraging ranges of insect pollinators that have been observed visiting the plants, including European Honeybees (*Apis mellifera*) (Beekman and Ratnieks 2001; T. Soderquist *in litt.* August 2022), the population is considered to consist of a single subpopulation as defined by IUCN (2022).

Typical stands of *Homoranthus croftianus* can be quite dense in areas of suitable habitat in depressions on the granite slabs, with up to 500 plants occupying areas as small as 600 m^2 (G. Phillips pers. obs. January 2021; Hunter 2022). Prior to the drought of 2017–2019 the total population was estimated to be a maximum of 1,500 mature individuals (DPE 2022*a*).

Following the drought, the population of mature individuals appears to have contracted by 10–15% (T. Soderquist *in litt.* August 2022). Though many mature plants survived the drought and are recovering strongly since, decline is still ongoing in some stands (DPE 2022a; J. Hunter *in litt.* July 2022; T. Soderquist *in litt.* August 2022). Post-drought surveys in October 2020 estimated a maximum of 1,360 individuals, though a proportion of this estimate consists of juvenile plants (Hunter 2022). Recruitment since the breaking of the drought has been variable between stands, with some stands being observed to have relatively strong recruitment (G. Phillips pers. obs. January 2021; J. Hunter *in litt.* July 2022) and others with limited recruitment or with lower seedling success due to mortality from herbivore browsing (T. Soderquist *in litt.* August 2022). Additionally, some stands still possess a portion of heavily drought affected individuals, which are not recovering and may yet die (DPE 2022a; Hunter 2022). This variability in seedling success and likely ongoing mortality means that recovery back to pre-drought numbers is unlikely to occur. Thus, the population is currently considered as a maximum of 1,275–1,360 mature individuals, with the upper bound defined by the upper post-drought survey estimate assuming all recorded juveniles grow to maturity, and the lower bound defined by assuming maximum estimated mortality following the 2017–2019 drought with total recruitment failure.

Area of Occupancy and Extent of Occurrence

The Area of Occupancy (AOO) of *Homoranthus croftianus* is estimated to be 4 km^2, calculated using 2 x 2 km grid cells, the scale recommended by IUCN (2022). The Extent of Occurrence (EOO) is estimated to be 0.26 km^2 based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). However, where EOO is less than or equal to AOO then IUCN guidelines recommend EOO estimates be changed to be equal to AOO to ensure consistency with the definition of AOO as an area that fits within EOO (IUCN 2022). Therefore, the EOO for *H. croftianus* is also estimated to be 4 km^2 in this assessment. Both EOO and AOO were calculated using ArcGIS (Esri 2015), enclosing all confirmed survey records and cleaned spatial datasets. Based on these estimates, *H. croftianus* has a very highly restricted AOO and EOO.

Number of Locations

When the most serious plausible threat of increased frequency, intensity and duration of drought due to climate change is considered (Ukkola *et al*. 2020), the sole subpopulation of *Homoranthus croftianus* can be considered a single threat-defined location, as per the IUCN definition (IUCN 2022), given the effects of drought are likely to be consistent across the full range of the species, and could plausibly affect any or all of the population in a single event, resulting in decline.

Ecology

Habitat

Homoranthus croftianus grows in shrubland and low woodlands in exposed situations from 900–1,200 m elevation on and around the vast granite outcrops of the unique granitic intrusion known as the Bolivia Hill Leucomonzogranite (Hunter 1998; Copeland *et al.* 2011; Geoscience Australia 2022; T. Soderquist *in litt.* January 2023). The species is typically found in shallow, sandy soils in depressions and erosional fissures on the outcrops, which are known to be high in sodium and potassium and are acidic in nature with a pH of 3.8–4.8 (Hunter 1998; Copeland *et al.* 2011; Bui *et al.* 2017). Bolivia Hill receives approximately 800–900 mm of rain annually (Hunter 2002). Given the open, desiccating environments typically found on the outcrops, species such as *H. croftianus* are not limited in growth by light availability, but by space, water, and nutrient availability. These characteristics, along with soil chemistry, are the likely drivers of habitat specificity in the species (Hunter 2003).

Homoranthus croftianus commonly co-occurs with *Callitris endlicheri, Eucalyptus prava, E. dealbata, Leucopogon neoanglicus, Micromyrtus sessilis, Kunzea bracteolata, Boronia anethifolia, Leptospermum nova-angliae, Acacia viscidula* and *Cryptandra lanosiflora* (Hunter 1998). Other threatened species listed on the NSW *Biodiversity Conservation Act 2016* also associate with *H. croftianus,* with *Acacia pycnostachya* commonly co-occurring, and *Boronia boliviensis* and *Eucalyptus boliviana* co-occurring in certain stands (Hunter 1998, 2002, 2022; G. Phillips pers. obs. January 2021).

Based on plot data and plant community type (PCT) mapping, *Homoranthus croftianus* is almost completely restricted to New England Rockplate Shrubland (PCT 3854) (Hunter 2002; DPE 2022b). The species may also occur in other low forest PCTs that fringe the outcrops.

Life History

Homoranthus species that reside on rock outcrops on the New England Tableland are typically obligate seeders, reliant on recruitment from the soil seedbank following major disturbances such as fire or drought (Clarke and Knox 2002; Clarke *et al.* 2009).

While the post-fire response of *Homoranthus croftianus* has not been directly recorded, it too is assumed to be an obligate seeder (Hunter 2002; OEH 2020). Post-drought observations of seedling recruitment accompanied with little to no reshooting from unhealthy plants following rain supports this inference (G. Phillips pers. obs. January 2021).

Obligate seeding species of rock outcrops are often long-lived, have low turnover of individuals, and maximise their use of the limited soil resources as these traits enable competitive advantages in the dry, harsh environments of the outcrops (Hunter 2003). *Homoranthus croftianus* has an expected lifespan of over 30 years (Hunter 2002) with rare germination outside of mass disturbance events (DPE 2022a) and dense, even-aged stands (G. Phillips pers. obs. January 2021). The species soil seedbank is also likely to be relatively short-lived, with above-ground persistence favoured (Hunter 2003). This is in line with findings in related *Darwinia* species (also in tribe Chamelaucieae), which have *in situ* seedbank half-lives of less than one year (Auld *et al.* 2000). Consequently, continual seed input is required in most seasons to maintain the soil seedbank (Auld *et al.* 2000) and so the primary juvenile period of *H. croftianus* is required to be reasonably short, estimated at less than five years (Hunter 2002).

Given the short-lived soil seedbank, the generation length of *Homoranthus croftianus* can be estimated using the age of first reproduction + z * length of reproductive period (IUCN 2022), where z is a constant between 0 and 1 calculated using survivorship and the relationship between fecundity and age. Using the above conservative lifespan estimate of 30 years, a value for z of 0.21 comparable to other woody shrub species (Fung and Waples 2017), and a maximum primary juvenile period of five years as estimated above, the generation length of *H. croftianus* is therefore estimated to be approximately 10 years.

Reproductive Ecology

Homoranthus croftianus has been recorded flowering sporadically throughout the year, although the primary flowering period appears to be from October to January (Copeland *et al.* 2011). Fruit production is maximal from January to February (G. Phillips pers. obs. January 2021).

The flowers of *Homoranthus* are protandrous as in other related Myrtaceae taxa, with the anthers dehiscing prior to anthesis to deposit pollen on the prominent hairs on the upper part of the style, which then elongates as the flower opens (Slater and Beardsell 1991; Hunter 1998). The stylar hairs then recede from the stigma as it develops and the flower transitions to the female phase, minimising self-pollination (Slater and Beardsell 1991). This presentation of pollen on the style, and stylar extension away from a nectar reward, minimises pollen deposition on non-pollinator floral visitors while also enabling larger pollinators like small birds to be effective, as well as maximising out-crossing between individuals (Slater and Beardsell 1991).

Given this floral morphology, it is likely that both insects and small birds are possible pollination vectors for *Homoranthus croftianus,* and both have been observed visiting plants. To date, four potential insect pollinators have been observed on *H. croftianus*: an unidentified fly, an unidentified native bee, a bee of the genus *Megachile*, and the European Honeybee (*Apis mellifera*) (T. Soderquist *in litt.* August 2022). An unidentified species of honeyeater has also been observed visiting *H. croftianus* and these birds are considered likely pollinators, though access to the flowers was noted to be somewhat restricted due to the relatively large size of the bird (T. Soderquist *in litt.* August 2022). Thus, the effectiveness of birds as pollinators may vary depending on the size and age of the plants and their ability to support the birds whilst feeding (T. Soderquist *in litt.* August 2022).

Seed Ecology

Dispersal of *Homoranthus* seed is initially highly localised, with almost all seed falling immediately below the parent plant once the fruit has ripened and this is also the case for *Homoranthus croftianus* (G. Phillips pers. obs. January 2021). Secondary dispersal is then predicted to be undertaken by ants, as is the case in *Darwinia* species with similar flower morphology (Auld 2009), which is common in other taxa found on infertile soils such as the granite-derived substrates on Bolivia Hill (Westoby *et al.* 1990). Ants have been shown to remove up to 80% of seed falling under *Darwinia* (Auld 2009), though the mean movement distance of seeds by ants in many taxa is often relatively small at 1–2 m (Hughes and Westoby 1992), and this is likely to be similar in *H. croftianus.* This removal of seeds by ants to underground nests may reduce seed predation as well as affect dormancy breaking, germination, and seedling emergence depending on the depth of burial, providing some buffering against stochastic effects of disturbances, such as hot fires that would otherwise kill seeds on the soil surface (Hughes and Westoby 1992), as long as ant burial is not beyond the shallow emergence depth for seed of this size (Moles and Westoby 2006).

Some *Homoranthus croftianus* seed appears to germinate without disturbance following sufficient rainfall *in situ* (G. Phillips pers. obs. January 2021; J. Hunter *in litt.* July 2022). Germination rates in laboratory settings of approximately 10% with no pre-treatment suggests that this limited germination is due to a non-dormant portion in the seedbank (RBGDT 2023). However, it is expected that the remaining portion of *H. croftianus* seeds are physiologically dormant, with dormancy released by favourable environmental conditions. Given the application of gibberellic acid alone does not appear to increase germination rates above 14% in the laboratory (RBGDT 2023), dormancy is strongly suspected to be relieved by a physical treatment such as heat shock, as found in obligate-seeding *Darwinia* species (Auld and Ooi 2009). Ideal temperatures for heat shock treatment to relieve dormancy in these species are typically 80–100° C (Auld and Ooi 2009), similar to conditions found at burial depths of 1–2 cm during a bushfire (Bradstock and Auld 1995). This indicates that intermittent wildfire likely plays a key role in the recruitment cycle and maintenance of *H. croftianus* stands. However, hotter fires producing soil temperatures above 100° C will likely result in increased seed mortality (Auld and Ooi 2009) and the subsequent decline or loss of stands.

Threats

The NSW Scientific Committee (1999) stated that *Homoranthus croftianus* "is threatened by grazing by goats and rabbits. The risk of extinction is high due to low population numbers." It has become apparent in recent years that the effects of increased frequency and duration of drought due to climate change and adverse fire regimes are serious threats to the *H. croftianus* population, while herbivore browsing is also noted as adversely affecting recruitment and growth in the species (OEH 2020; DPE 2022a; J. Hunter *in litt.* July 2022; T. Soderquist *in litt.* August 2022).

Increased frequency and duration of drought due to climate change

Increased frequency, intensity and duration of drought is contributing to continuing decline in the *Homoranthus croftianus* population and is strongly inferred to do so into the future. Prior to the intense 2017–2019 drought there was an estimated maximum of 1,500 mature individuals in the population with limited seedling recruitment (DPE 2022a; T. Soderquist *in litt.* August 2022). Post-drought, surveys have recorded many mature individuals surviving and returning to good health by producing vigorous new growth and renewed reproductive ability (DPE 2022a; J. Hunter *in litt.* July 2022; T. Soderquist *in litt.* August 2022). However, there was still a predicted loss of 10–15% of mature individuals, as well as the death of all seedlings recorded prior to the drought (T. Soderquist *in litt.* August 2022). This, combined with the continuing death of a number of unhealthy mature plants that have not recovered since the breaking of the drought (DPE 2022a; Hunter 2022), means that the population has reduced from a pre-drought maximum estimate of 1,500 mature individuals to a current maximum estimate of 1,275–1,360 mature individuals.

Drought is likely to increase in frequency, intensity and duration in the future in areas occupied by the species, representing an ongoing threat to *Homoranthus croftianus* (Reichstein *et al.* 2013; Trenberth *et al.* 2013; Ukkola *et al.* 2020). While predicting the effects of future droughts and how they affect individual species is difficult (Cook *et al.* 2018; De Kauwe *et al.* 2020), the observed drought-induced mortality in *H. croftianus* highlights that drought has an adverse effect on the species. Indeed, these projected changes are already becoming more consistent with increased reports of severe drought affecting forest and woodland ecosystems across eastern Australia (Fensham *et al.* 2009; Allen *et al.* 2015; De Kauwe *et al.* 2020). As such, it can be reasonably inferred that future mortality events in *H. croftianus* due to prolonged and severe drought are likely to become more common.

Under future climate scenarios, the New England region in which *Homoranthus croftianus* occurs is predicted to become hotter, have fewer colder nights under 2°C, and more hot days over 35°C annually by the year 2079 (AdaptNSW 2023). These shifts will not only exacerbate the mortality of *H. croftianus* during droughts when they occur, but also possibly reduce the competitive advantage that maintains the stands on the rocky outcrops they currently occupy. The high levels of floral insularity, including high numbers of obligate-seeding taxa, on the rocky outcrops of the New England Tableland are largely maintained by the harsher, relatively drier environments they encounter compared to the wetter habitats that surround the outcrops (McGann 2002; Hunter 2003). This means that a reduction in climatic differences between outcrops and adjacent vegetation, brought about by increasing aridity in the surrounding landscape, will facilitate a shift to a more uniform flora between the outcrops and adjoining landscape (Hunter 2003). Indeed, taxa found more commonly around outcrops of the New England Batholith appear to increase in relative abundance on the outcrops with higher mean temperatures as more outcrop-dependent taxa reduce in relative abundance under the same conditions (McGann 2002). Thus, the habitat quality and total abundance of *H. croftianus* is strongly inferred to decrease in time with increasing air temperatures as their competitive advantage is reduced and more ubiquitous taxa migrate onto the outcrops, further amplifying the longer-term effects of mortality caused by increased drought occurrences. “Anthropogenic Climate Change” is listed as a Key Threatening Process under the *NSW Biodiversity Conservation Act 2016.*

Adverse fire regimes

Adverse fire regimes may cause decline in the *Homoranthus croftianus* population by way of reducing competitive advantages and destroying soil seedbanks required to replace burnt stands if hot fires were to become more frequent on Bolivia Hill in the future. Currently, Bolivia Hill has a very infrequent fire regime, with fires impacting the *H. croftianus* stands recorded in 1964/65 (fuel reduction burn), the mid-1970s (fuel reduction burn) and October 2002 (arson ignited wildfire) (Morsley and Falconer 1999; NPWS 2022). Sporadic, localised wildfires have also occurred elsewhere in the reserve approximately once every five years (NPWS 2022). The only large-scale wildfires recorded across Bolivia Hill are the 1964/65 and 2002 fires (NPWS 2011), meaning *H. croftianus* has not historically been placed under pressure from frequent fires of any intensity.

Rock outcrops are known to support large numbers of obligate seeding species that are sensitive to changes in fire regimes, having evolved in areas that act as fire shadows where the landscape prevents too regular a passage of fire, burning only intermittently, and thus enabling the regeneration of stands (Clarke 2002). The life history strategy of *Homoranthus croftianus* as an obligate-seeding species which favours aboveground persistence by being relatively long-lived, reflects the fact that it has evolved in a fire regime where hot fires that remove all biomass are infrequent (Hunter 2003). If such fire events become more common however, this will enable increased migration of taxa from the surrounding vegetation, especially resprouting species, by decreasing the habitat quality and thus competitive advantages of outcrop-dependent species, which in turn may become less abundant (Hunter 2003).

Increased passage of severe fires, which overcome typical landscape controls to burn rock outcrops, such as those following severe drought, could have a detrimental effect on *Homoranthus croftianus* by eliminating greater proportions of the soil seedbank along with aboveground plants. Fires that directly impact outcrops can be severe in nature, with intensity being enhanced by natural fuel loads building up in vegetation at the base of the outcrops (Buckman *et al.* 2021). Thus, fires that breach the top of outcrops can also cause elevated soil temperatures in the skeletal soil deposits found there. This is problematic for species such as *H. croftianus* as soil heating above 100°C likely eliminates much of the soil seedbank, as seen in related *Darwinia* (Auld and Ooi 2009), and these temperatures are commonly reached in the top 1 cm of the soil profile in severe wildfires (Bradstock and Auld 1995). Fires of this nature could therefore easily result in the elimination of much of the soil seedbank as well as aboveground plants, causing complete loss or large reductions of stands in a single fire event, especially if the soil seedbank is in a depleted state due to prior drought or fire. Given high severity fires in turn make the landscape more prone to further occurrences of high severity fires (Barker *et al.* 2021), such fires could rapidly reduce the *H. croftianus* population if they increase in frequency by not providing sufficient time for the soil seedbank to properly develop.

Potential losses due to increased fire frequency may be further enhanced following drought episodes, which can increase fuel loads (Nolan *et al.* 2020). Thus, more regular hot fires can induce a spiral of decline from which *H. croftianus* may not recover if other threats such as drought and browsing of seedlings also continue to adversely affect the population. Currently, no direct loss of stands due to such fires has been recorded for *H. croftianus* and so it is currently considered a potential future threat, though it is one with a high degree of seriousness if it were to occur given the predicted warmer future climate (AdaptNSW 2023). “High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition” is listed as a Key Threatening Process under the *NSW Biodiversity Conservation Act 2016*; and “Fire regimes that cause declines in biodiversity” is a listed Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Conversely, the exclusion of appropriate fire from the landscape for too long may also induce decline in the *Homoranthus croftianus* population. Laboratory results and *in situ* observations, as well as data from related *Darwinia* species, show that *H. croftianus* likely produces a high (>80%) proportion of seeds with physiological dormancy released by the passage of fire that heats the soil above 80°C (Auld and Ooi 2009; T. Soderquist *in litt.* August 2022; RBGDT 2023). This means that the species, like other obligate-seeding taxa that occur on rock outcrops, requires the intermittent passage of fire to replenish stands before they senesce to maintain relative abundances (McGann 2002; Hunter 2003). Given the fire history of Bolivia Hill and the suspected lifespan of >30 years (Hunter 2002), the passage of wildfire at least every 30–40 years possibly maintains the population of *H. croftianus* long-term, however, this remains untested.

Browsing by herbivores

Browsing by herbivores is a noted issue for *Homoranthus croftianus*, as it is for many rocky outcrop endemics (Hunter 2003), especially on seedlings (DPE 2022a), and during times of drought (J. Hunter *in litt.* July 2022). Feral Goats (*Capra hircus*), Rabbits (*Oryctolagus cuniculus*), and native macropods such as Wallaroos (*Osphranter robustus*) have all been recorded as possible browsers of *H. croftianus* (DPE 2022a; T. Soderquist *in litt.* August 2022). Seedlings appear to be susceptible to herbivores regardless of climatic conditions, as observed in other *Homoranthus* species (G. Phillips pers. obs. August 2020, November 2021; T. Soderquist *in litt.* August 2022). During drought however, mature plants appear to be more heavily browsed given apparent differences in the health and growth of fully exposed plants and those which have been caged to prevent herbivory (J. Hunter *in litt.* July 2022; T. Soderquist *in litt.* August 2022). Grazing can lower the reproductive ability of the plants and consequently the development of the soil seedbank, which in conjunction with other drought-related mortality, can reduce stand resilience and the ability to recover from drought and/or wildfire.

Feral goats are active on Bolivia Hill and have been regularly recorded within the distribution of *Homoranthus croftianus* (T. Soderquist pers. comm. August 2022).

Goats can rapidly degrade vegetation communities through over-grazing and erosion of soils (DPE 2021a), especially during drought. Regular control of feral goats is undertaken in the Bolivia Hill Nature Reserve (NPWS 2011). However, given the evidence of stronger growth of caged *H. croftianus* compared to exposed plants post-drought (T. Soderquist *in litt.* August 2022), it is likely that if this control ceased, goat impacts would become more noticeable on mature plants. It is highly likely that goat browsing maintains pressure on seedling recruitment also, so it is inferred that their continued presence suppresses recruitment and the proportion of seedlings that reach reproductive maturity. This contributes to continuing decline in the habitat and population of *H. croftianus.* "Competition and habitat degradation by feral goats (*Caprus hircus*)" is listed as a key threatening process under the NSW *Biodiversity and Conservation Act 2016*.

Rabbits, even at low densities, can also have significant impacts on threatened flora by preventing regeneration through their grazing habits and contributing to erosion by warren construction (Western LLS 2018, DPE 2021b). Given the skeletal soils of outcrops are readily washed away by the high levels of runoff they experience following rain (Hunter 2003), any increased erosion in these landscapes caused by rabbits can lead to rapid changes in habitat quality for species such as *Homoranthus croftianus.* "Competition and grazing by the feral European rabbit" is listed as a key threatening process under the NSW *Biodiversity and Conservation Act 2016*.

While macropod browsing may be considered a natural process, populations of larger macropod species can be artificially inflated in remnant bushland and conservation reserves due to surrounding agricultural land uses, leading to increased browsing pressure (NPWS 2002). Macropod browsing may also be amplified in drought as other more palatable species are exhausted (NPWS 2002; T. Soderquist pers. comm. September 2022). This may limit post-drought recovery of *Homoranthus croftianus,* compounding the impacts of browsing by feral goats and rendering the population more susceptible to the impacts of wildfire.

Assessment against IUCN Red List criteria

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

Criterion A *Population size reduction*

Assessment Outcome: Data Deficient.

Justification: *Homoranthus croftianus* has suffered some loss of individuals due to the combined effects of increased frequency and duration of drought due to climate change and browsing by feral goats in the past three generations. However, this loss is not significant enough to meet the thresholds for listing under Criterion A. Over the course of the 2017–2019 drought, a population reduction of approximately 10–15% was observed from a pre-drought maximum of 1,500 mature individuals to a current maximum of 1,275–1,360 mature individuals (T. Soderquist *in litt.* August 2022). While many plants that suffered in the drought are returning to good health, others remain in ill health and may yet succumb in time (Hunter 2022; J. Hunter *in litt.* July 2022; T. Soderquist *in litt.* August 2022). Seedling recruitment to replace this loss of mature individuals is currently suppressed by browsing by herbivores such as feral goats (T.

Soderquist *in litt.* August 2022) and may continue to be suppressed into the future by changes in fire regimes that do not provide conditions conducive to germination and stand maintenance. Given the most serious threat of increased frequency and duration of drought due to climate change is unlikely to abate given future climate scenarios for the New England region (AdaptNSW 2023), a population reduction of 10–15% where the causes of reduction have not ceased has occurred in *H. croftianus* since 2017. This is well within the three-generation timeframe of 30 years for the species, however future declines remain likely but of unknown magnitude. This means that the full magnitude of decline over a three-generation timeframe from the commencement of the known declines from 2017 up to 2047 cannot be estimated with confidence, precluding assessment under Criterion A.

Criterion B *Geographic range*

Assessment Outcome: Critically Endangered under Criterion B1(a)(b iii v) and B2(a)(b iii v).

Justification: *Homoranthus croftianus* is endemic to a small area of the Bolivia Range on the NSW Northern Tablelands and has a very highly restricted geographic distribution. The Area of Occupancy (AOO) has been calculated as 4 km^2, meeting the threshold for listing as Critically Endangered. The Extent of Occurrence (EOO) has been calculated as 0.26 km^2, however, where EOO is less than or equal to AOO then IUCN guidelines recommend EOO estimates be changed to be equal to AOO to ensure consistency with the definition of AOO as an area that fits within EOO (IUCN 2022). Therefore, EOO is also calculated as 4 km^2, meeting the threshold for listing as Critically Endangered.

In addition to these thresholds, at least two of three other conditions must be met to qualify for listing under Criterion B. 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 Critically Endangered due to having one threat-defined location.

   Justification: *Homoranthus croftianus* is found at one threat-defined location when considering the most serious plausible threat of increased frequency and duration of drought due to climate change.

   Homoranthus croftianus is not considered severely fragmented as all individuals are found in a large, non-isolated subpopulation and the subpopulation is considered viable.

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, inferred and projected for (iii) area, extent and/or quality of habitat and (v) number of mature individuals.

Justification: Decline has been observed and is strongly inferred to continue in the area, extent and quality of habitat and number of mature individuals of *Homoranthus croftianus* due to the combined effects of increased frequency and duration of drought due to climate change, adverse fire regimes, and browsing by feral and native herbivores. Some small stands of *H. croftianus* previously identified by botanists no longer appear to be extant, having not been relocated for some time (T. Soderquist pers. comm. August 2022). Additionally, during and following the 2017–2019 drought, a reduction has occurred in the *H. croftianus* population, with the number of mature individuals estimated to have declined by up to 15% (T. Soderquist *inlitt.* August 2022). Recruitment success since the drought has been variable between stands, with some stands being observed with relatively strong recruitment (G. Phillips pers. obs. January 2021; J. Hunter *in litt.* July 2022) and others with limited recruitment or with lowered seedling success due to herbivore browsing (T. Soderquist *in litt.* August 2022). Additionally, while many plants that suffered in the drought are returning to good health, others remain in ill health and may yet die (Hunter 2022; J. Hunter *in litt.* July 2022; T. Soderquist *in litt.* August 2022). Under projected future climate conditions for the region, drought is expected to increase in frequency and duration (Reichstein *et al.* 2013; Trenberth *et al.* 2013; Allen *et al.* 2015; AdaptNSW 2023). Therefore, it can be reasonably inferred that future *H. croftianus* mortality events, such as that seen in 2017–2019, will become more common, exacerbating observed declines. A warming climate also creates a situation whereby the prevailing environmental conditions that obligate-seeding rocky outcrop species require to retain competitive advantages are reduced (McGann 2002; Hunter 2003). Warmer air temperatures also increase the risk of more frequent severe fires breaching the outcrops, which may destroy significant portions of soil seedbanks in obligate-seeding species (Auld and Ooi 2009), thus inducing rapid decline. Conversely, recruitment episodes to replenish senescent stands of rocky outcrop species such as *H. croftianus* may be limited if appropriate fire is excluded for too long (McGann 2002; Hunter 2003). The combination of these threats indicates that the quality and availability of habitat and number of mature individuals of *H. croftianus* are likely to remain under pressure, and currently observed declines are strongly inferred to continue into the future.

c) Extreme fluctuations.

Assessment Outcome: Not met.

Justification: *Homoranthus croftianus* is a relatively long-lived shrub and is unlikely to undergo extreme fluctuations.

Criterion C Small population size and decline

Assessment Outcome: Vulnerable under Criterion C1 and C2(a)(ii)

Justification: The current estimated population for *Homoranthus croftianus* is a maximum of 1,275–1,360 mature individuals, meeting the threshold for Endangered or Vulnerable.

In addition to this threshold, one of at least two other conditions must be met to qualify for listing under Criterion C. These conditions 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: Met for Vulnerable.

Justification: *Homoranthus croftianus* is undergoing continuing decline due to the combined effects of increased frequency and duration of drought due to climate change, adverse fire regimes, and browsing by feral and native herbivores. Stands of *H. croftianus* previously identified by botanists no longer appear to be extant, having not been relocated for some time (T. Soderquist pers. comm. August 2022). Additionally, since the start of the 2017–2019 drought an observed decline of up to 15% of mature individuals has occurred (T. Soderquist *in litt.* August 2022). Given this constitutes a loss of greater than 10% within three generations (30 years) for the species, the Vulnerable threshold is met.

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

Assessment Outcome: Met for Vulnerable.

Justification: Decline has been observed and is strongly inferred to continue in the number of mature individuals of *Homoranthus croftianus* due to the combined effects of increased frequency and duration of drought due to climate change, adverse fire regimes, and browsing by feral and native herbivores.

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

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

Assessment Outcome: Not met.

Justification: The population of *Homoranthus croftianus* consists of one subpopulation with maximum pre-drought numbers estimated to be approximately 1,500 mature individuals (DPE 2022a). Given a loss since 2017 of up to 15% of mature individuals, this means that the subpopulation now has approximately 1,275–1,360 mature individuals (T. Soderquist *in litt.* August 2022).

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

Assessment Outcome: Met for Vulnerable.

Justification: The population of *Homoranthus croftianus* consists of a single subpopulation.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Not met.

Justification: *Homoranthus croftianus* is a relatively long-lived shrub and is unlikely to undergo extreme fluctuations.

Criterion D Very small or restricted population

Assessment Outcome: Criterion met for Vulnerable D2.

Justification: *Homoranthus croftianus* is currently estimated to have a maximum population of 1,275–1,360 mature individuals, with numbers unlikely to be below 1,000 based on recent survey data (Hunter 2022). However, it also has a very restricted AOO of 4 km^2 and occurs at a single threat-defined location, rendering it prone to the effects of human activities and stochastic events that may rapidly drive the species to extinction in a very short time period.

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: Criterion not met.

Justification: *Homoranthus croftianus* is currently estimated to have a maximum population of 1,275–1,360 mature individuals, with numbers unlikely to be below 1,000 based on recent survey data (Hunter 2022).

D2. Population with a very restricted area of occupancy (typically less than 20 km^2) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming CR or even EX in a very short time period.

Assessment Outcome: Criterion D2 is met for Vulnerable.

Justification: *Homoranthus croftianus* has an estimated AOO of 4 km^2 and only occurs at a single threat-defined location. Repeated drought episodes in combination with grazing pressure from feral goats and the increased likelihood of frequent fires, are likely at this location and are a plausible threat that may lead *H. croftianus* to become Critically Endangered or even Extinct in a very short time period.

Criterion E Quantitative Analysis

Assessment Outcome: Data deficient.

Justification: Currently there is insufficient data to undertake a quantitative analysis to determine the extinction probability of *Homoranthus croftianus.*

Conservation and Management Actions

Homoranthus croftianus 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. *H. croftianus* sits within the site-managed management stream of the SoS program.

Activities to assist this species currently recommended by the SoS program (DPE 2022a) include:

<u>Habitat loss, disturbance and modification</u>

- Install and maintain cages around select individuals at all sites to protect a subsample of each from herbivory and ensure seed production and recruitment.
- Ensure minimum 20-year fire interval to allow for sustainable recruitment.

<u>*Ex situ* conservation</u>

- Identify suitable translocation sites and establish new subpopulations representative of as much wild genetic diversity as possible.
- Research into seed biology including germination cues in soil and *ex situ* seedbanks.

<u>Survey and monitoring</u>

- Monitor species recruitment and condition at 6-month intervals to detect the full impacts of threats on the species.
- Assessment of pest animal abundance to advise appropriate management.

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Expert Communications

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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:
Homoranthus croftianus was found to be Critically Endangered under Clause 4.3 (a) (d) (e i, iii).

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Clause not met.

(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: Critically Endangered under Clause 4.3 (a) (d) (e i,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:	
		(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: Vulnerable under Clause 4.4 (c) (d iii) (e i,ii (B)) .

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

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

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