

NSW Threatened Species Scientific Committee

Conservation Assessment of *Boronia hapalophylla* Duretto, F.J.Edwards & P.G.Edwards (Rutaceae)

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***Boronia hapalophylla* Duretto, F.J.Edwards & P.G.Edwards (Rutaceae)**

Distribution: Endemic to NSW

Current EPBC Act Status: Not listed

Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act: Delist.

Reason for change: Non-genuine change based on increased data on distribution and population numbers and knowledge of threats to the species.

Summary of Conservation Assessment

Boronia hapalophylla was found to be ineligible for listing as a threatened species as none of the Criteria were met.

Description and Taxonomy

Boronia hapalophylla is a conventionally accepted species within *Boronia* section *Valvatae* within which it is regarded as an isolated taxon with few to no immediate relatives in New South Wales (NSW) (Duretto *et al.* 2004). It is described by Duretto *et al.* (2004) as an "erect, much branched shrub to 3 m tall, very open and spindly, often supported by other species when tall. Multiangular stellate hairs sessile, with up to 15 rays; rays to 0.5 mm long, unicellular, free, firm, straight, glossy, smooth, white to yellow. Branches terete to slightly quadrangular in cross section, decurrent leaf bases lacking, not obviously glandular, with no massive cork development, with a moderately dense stellate indumentum, becoming glabrous with age, regrowing from a rootstock after disturbance. Leaves simple, opposite, rarely sub-opposite or in whorls of three, not conspicuously glandular, sessile to subsessile, leaf base so strongly attenuate as to appear petiolate, apparent petiole to 1.5 mm long; lamina narrow-elliptic to elliptic to lanceolate, (13–)18–50(–70) mm long, (1–)3.5–12 mm wide, strongly discolourous, paler beneath, dorsiventral, with palisade mesophyll above and spongy mesophyll below; tip acute; base strongly attenuate; margins entire, slightly recurved to revolute; midrib prominently raised abaxially, with tightly packed parenchyma with secondary thickening between midvein and abaxial epidermis, impressed adaxially; adaxial surface with a sparse to moderately dense, stellate indumentum; abaxial surface with a dense, heterogenous indumentum of two hair types: a moderately dense layer of multiangular stellate hairs over a dense layer of peltate stellate hairs. Inflorescence axillary, 1–5-flowered, with a dense stellate indumentum; peduncle absent, or sometimes 2–5 mm long in inflorescences with 3–5 flowers; prophylls minutely unifoliolate, often leaf-like, 1.5–7(–20) mm long, with a dense stellate indumentum, or indumentum as leaves; anthopodia [pedicels] 2–6.5 mm long. Sepals broadly ovate-deltate, shorter and narrower than petals, acuminate, valvate in bud, 5–7 mm long, 3–4.5 mm wide, enlarging to 10 mm long and

NSW Threatened Species Scientific Committee

7 mm wide with mature fruit, persistent; adaxial surface densely and minutely pubescent, becoming glabrous towards base; abaxial surface with a dense stellate indumentum. Petals pink, valvate in bud, (6–)8–10 mm long, enlarging to 15 mm long with mature fruit, with midvein raised abaxially, persistent; adaxial surface sparsely pilose, becoming glabrous towards base; abaxial surface with a dense stellate indumentum. Stamens all fertile, filaments bearing stiff, simple hairs abaxially and on margins below glandular tip; sepaline filaments clavate, tapering to anther connective, 2–2.5 mm long, the distal 0.5–1 mm prominently glandular; petaline filaments, c. 1.5 mm long, the distal end glandular; anthers monomorphic, glabrous; anther appendage erect or reflexed. Disc entire, glabrous, rarely with slight swelling opposite sepaline stamens. Ovary glabrous or rarely with few stellate hairs at apex; style glabrous or rarely with scattered stellate hairs at base; stigma slightly wider than style. Cocci c. 7 mm long, c. 3.5 mm wide, glabrous or hirsute. Seeds black, shiny, 5–6 mm long, 2.5–3 mm wide; surface at magnification tuberculate; tubercles free.”

Boronia hapalophylla has also been known as *Boronia* sp. ‘Shannon Creek’ (P & J Edwards 3) prior to being formally described in 2004 (Duretto *in litt.* September 2003). It is closest morphologically to the locally occurring *Boronia rosmarinifolia* and *B. chartacea* and is differentiated from both by the larger sepals (5–10 mm long, 3–7 mm wide *cf.* 2–4.5 mm long, 1–3.5 mm wide) when in flower and the sparse to dense indumentum on the adaxial (upper) surface of the leaves (*cf.* glabrous) (Duretto *et al.* 2004).

Distribution and Abundance

Boronia hapalophylla is endemic to the Kangaroo Creek Sandstone geological formation along the southern edge of the Clarence-Moreton Basin in northern NSW (NSW Scientific Committee 2004; NSW NPWS 2009). This area lies within the South Eastern Queensland Bioregion on the traditional lands of the Gumbaynggir First Nations people (Horton 1996; Department of Agriculture, Water and Environment 2012).

In 2004 the NSW Scientific Committee concluded that “*Boronia hapalophylla* is currently known on hillslopes and ridge tops above Shannon Creek (near Coutts Crossing), on Kangaroo Creek Sandstone. It is found in sclerophyll woodland where it is generally sparsely distributed with some dense patches. Some of the occurrences are in Chambigne Nature Reserve. Based on available habitat maps and density estimates the species is known over a range of 5 kilometres by 3 kilometres.” (NSW Scientific Committee 2004). Since the 2004 determination however, there have been substantial targeted surveys across the region and several historical specimens of *B. rosmarinifolia* from the area have been re-determined as *B. hapalophylla*, increasing the known abundance and range of the species significantly (Sheringham 2021; P. Sheringham *in litt.* April 2022).

As well as many new records within the Shannon Creek and Chambigne Nature Reserve area being found, targeted surveys since 2019 have located sizeable new subpopulations, expanding the species’ range substantially to the southeast and east (Table 1) (Sheringham 2021). Further to this, at least two confirmed yet unsurveyed sites have been reported from private property, one along the Orara River where the plants are described as being scattered at low density (F. Forest *in litt.* May 2022) and

NSW Threatened Species Scientific Committee

one at Dundoo Creek to the northeast of Sherwood Nature Reserve where the abundance was not recorded (Sheringham 2021, P. Sheringham *in litt.* April 2022) (Appendix 2; Distribution Map). Thus, the population of *B. hapalophylla* is currently known from 13 sites, with five sites included in gazetted conservation reserves, four others in private or local government land set aside for conservation purposes, two in vacant Crown land and two in state forests. The population is also considered to consist of three subpopulations, given studies on other *Boronia* have shown that patches separated by distances of 3–4 km have less than one migrant per generation due to limited dispersal and gene flow (Shapcott *et al.* 2005).

Table 1 – Abundance of *Boronia hapalophylla* across all known sites as of May 2022.

Site	Tenure	Subpopulation	Subpopulation Count ¹
Flaggy Creek Nature Reserve	NPWS	Orara Valley	108
Tallawudjah Nature Reserve	NPWS	Orara Valley	131
Hayards Crossing Vacant Crown land	Crown Land	Orara Valley	1457
McGills Road VCA	Private Conservation	Orara Valley	40
Orara Way Crown Land	Crown Land	Orara Valley	14
'Bull Paddock', Orara River	Aboriginal Land Council	Orara Valley	unknown
Chambigne Nature Reserve	NPWS	Shannon Creek	241
Shannon Creek Dam	Clarence Valley Council Reserve	Shannon Creek	658
Sherwood Nature Reserve	NPWS	Orara Valley	8640
Conglomerate State Forest	Forestry Corporation of NSW	Orara Valley	546
Dundoo Creek	Private Conservation	Orara Valley	unknown
Newfoundland State Forest	Forestry Corporation of NSW	Yuraygir	39
Yuraygir State Conservation Area	NPWS	Yuraygir	5337
Total Population Surveyed			17780

¹Census data from Sheringham (*in litt.* April 2022).

Specimens previously identified as *B. rosmarinifolia*, which are now regarded as *B. hapalophylla* (e.g. NSW243813), indicate other unsurveyed occurrences in the direction of Halfway Creek may also exist. Other current records of *B. rosmarinifolia* in the Kremnos area without voucher specimens lodged at herbaria are also very likely to be mis-identified *B. hapalophylla* given the former species only appears to occur on deeper coastal sands in the region and not on the Kangaroo Creek Sandstone south of the Clarence River (P. Sheringham *in litt.* April 2022, June 2022). There is also a

NSW Threatened Species Scientific Committee

high likelihood that further unrecorded individuals and subpopulations of *B. hapalophylla* exist in other poorly surveyed areas of intact habitat on Kangaroo Creek Sandstone, such as in private lands north of Tallawudjah Nature Reserve and in Koukandowie Nature Reserve (P. Sheringham *in litt.* April 2022).

There has been some phenotypic variation reported between different subpopulations (J. Edwards *in litt.* April 2022; F. Forest *in litt.* May 2022), however the genetic significance of this variation has not been investigated, and we follow the NSW Herbarium in recognising all subpopulations cited in this document, including those at Sherwood and Flaggy Creek, as *Boronia hapalophylla* (RBGDT 2023).

Currently, the population of *Boronia hapalophylla* is regarded as a minimum of 17,780 plants based on census data (P. Sheringham *in litt.* April 2022), however the true number is likely much higher considering this does not include the two confirmed but unsurveyed sites on the Orara River and at Dundoo Creek. Substantially more plants are also likely in large, unsurveyed areas of potential habitat in Sherwood Nature Reserve, Yuraygir State Conservation Area and Tallawudjah Nature Reserve (Sheringham 2021). All plants surveyed thus far are considered mature individuals as most plants recorded in recent surveys have been reproductively mature, including seedlings only apparent after fires in 2019 which were found to have a very short primary juvenile period (less than two years) and for which survivorship appears high (Sheringham 2021, G. Phillips pers. obs. November 2021).

The Extent of Occurrence (EOO) is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022) and was measured at 572 km². Area of Occupancy (AOO) was calculated using 2 x 2 km grid cells, the scale recommended by IUCN (2022) and was calculated to be 208 km². Both EOO and AOO were calculated using ArcGIS (Esri 2015), enclosing all recent confirmed survey records and cleaned spatial datasets. Based on these estimates, *Boronia hapalophylla* has a highly restricted EOO and AOO.

Boronia hapalophylla is regarded as having three threat-defined locations when the most serious plausible threat of changed fire regimes is considered. These three locations are: 1) All records from Chambigne Nature Reserve southwest to Flaggy Creek Nature Reserve; 2) Sherwood Nature Reserve and areas immediately northeast; and 3) the Yuraygir subpopulation. This is based on the fire history of the region including previous fire extent and known biogeographical barriers to fire (NSW NPWS 2009).

Ecology

Habitat

Boronia hapalophylla grows on sandy soils derived from Kangaroo Creek Sandstone in open Eucalypt woodland, forests and heath with a typically sparse understorey, though is also sometimes found in thicker vegetation in gullies (Duretto *et al.* 2004; Sheringham 2021). Co-occurring species include *Eucalyptus planchoniana*, *E. pyrocarpa*, *E. signata*, *E. psammitica*, *Corymbia gummifera*, *C. trachyphloia*, *Angophora costata* and vulnerable *A. robur* in the tree layer along with *Pultenaea rostrata*, *Lambertia formosa*, *Leptospermum trinervium*, *Acacia myrtifolia*, *Banksia*

NSW Threatened Species Scientific Committee

oblongifolia, and endangered *Melichris hirsutus* in the shrub layer (Duretto *et al.* 2004; Sheringham 2021). The species occupies hillslopes and ridge crests with sandy soils of varying depth and not the most skeletal soils on outcropping sandstone sites (NSW Scientific Committee 2004; Sheringham 2021).

Based on species lists in Sheringham (2021), the most common Plant Community Types (PCT) harbouring *B. hapalophylla* include Clarence Sandstone Stringybark Heathy Woodland (PCT 3568), Clarence Sandstone Bloodwood-Stringybark Forest (PCT 3564), Clarence Sandstone Rises Spotted Gum Grassy Forest (PCT 3422) and Clarence Sandstone Rough-barked Apple Shrub Forest (PCT 3567) (DPE 2022). In the Shannon Creek subpopulation, *B. hapalophylla* has been recorded growing in the regionally unique *Corymbia trachyphloia* - *Eucalyptus psammitica* Ecological Community which has previously been considered for a threatened ecological community listing (NSW Scientific Committee 2010) and aligns most closely with the PCT Clarence Sandstone Bloodwood-Stringybark Forest (PCT 3564) (DPE 2022).

Life History

Boronia are typically either obligate seeding or facultative seeding species in response to major disturbances such as fire (NSW NPWS 2002). *B. hapalophylla* appears to be a facultative seeding species as it has been observed to both vigorously reshoot from rootstock after fire as well as producing copious seedlings in the post-fire environment after wildfire (Duretto *et al.* 2004; Sheringham 2021; G. Phillips pers. obs. November 2021; J. Edwards *in litt.* April 2022). Mature plants in the northern Shannon Creek subpopulation, which are recorded as being larger plants on average, resprout vigorously from the base following fire (J. Edwards *in litt.* April 2022), whereas fewer resprouting plants have been recorded in the southern subpopulations which tend to have smaller mature plants on average and post-fire seedling growth appears to be favoured (Sheringham 2021). This however may be an artefact of the fire history of the sites, with most southern subpopulations being burnt far more regularly (NSW NPWS 2022; J. Edwards *in litt.* April 2022), and so the resulting smaller average mature individuals may be less likely to resprout and more likely to rely on seedling recruitment to replenish populations post fire.

Observations from the Yuraygir subpopulation indicate a primary juvenile period of less than two years for *B. hapalophylla*, with seedlings germinating after wildfire in January 2020 becoming reproductively mature and bearing viable seed by November 2021 (G. Phillips pers. obs. November 2021; Sheringham 2021). Plants in the Shannon Creek catchment that have been observed resprouting after fire are also recorded as being reproductively mature within two years, indicating a secondary juvenile period of approximately that length (J. Edwards *in litt.* April 2022). *B. hapalophylla* also appears to have a very high maturation rate in seedlings, with the majority of recruits at the Yuraygir site in November 2021 bearing fruit and viable seeds (G. Phillips pers. obs. November 2021).

The lifespan of *B. hapalophylla* is currently unknown. Other species of *Boronia* with similar growth forms are predicted to have an average lifespan of 10-15 years, so this may be reasonably inferred to be similar for *B. hapalophylla* (Auld 2001; NSW NPWS 2002). In lieu of soil seedbank or germination data, generation length can be estimated using the age of first reproduction + $z \times$ length of reproductive period (IUCN 2022),

NSW Threatened Species Scientific Committee

where z is a constant between 0 and 1 calculated using survivorship and the relationship between fecundity and age (Fensham *et al.* 2020). Using the above estimate of lifespan, a value for z of 0.21 comparable to other woody shrub species (Fung and Waples 2017) and an age of first reproduction of two years as above, the generation length of *B. hapalophylla* is therefore estimated to be approximately four to five years.

Reproductive ecology

Boronia hapalophylla flowers throughout the year, with peak flowering and fruiting occurring in spring (Duretto *et al.* 2004). The southern subpopulations have been recorded as flowering more regularly from July to September (Sheringham 2021; J. Edwards *in litt.* April 2022) with fruit then ripening from November to December (G. Phillips pers. obs. November 2021).

Pollination in *B. hapalophylla* has not been studied, however all other species in *Boronia* section *Valvatae* (to which *B. hapalophylla* belongs) are known to be self-incompatible, requiring outcrossing for successful pollination to occur (Weston *et al.* 1984). Potential pollinators recorded interacting with *Boronia* include sawflies, beetles, flies, moths, butterflies and at least 12 genera of bee which appear to be the most common pollinators across multiple *Boronia* species (Armstrong 1979).

Seed ecology

Sclerophyllous *Boronia* species typically employ ballistic release of seeds for initial dispersal (Auld 2001) and structures enabling this are apparent in the capsules of *B. hapalophylla* (G. Phillips pers. obs. November 2021). Seeds are then aided in moving further by dispersal by ants (myrmecochory), a common trait in species found on infertile soils such as the Kangaroo Creek sandstone (Westoby *et al.* 1990). The ants are drawn to the seeds by the presence of a lipid-rich elaiosome, another trait commonly found in species in *Boronia* section *Valvatae* (Auld 2001; Mackenzie *et al.* 2016). *B. hapalophylla* is almost certainly reliant on these traits also, utilising dual seed dispersal modes to maximise dispersal distance. Dispersal distances are likely to remain small overall however, with ballistic dispersal able to move seeds up to a few metres distance depending on the size of the parent plant and ants typically only moving seeds up to two metres further, however ant-assisted movements of up to 20 metres are reported in some species (Hughes and Westoby 1992; Auld 2001; NSW NPWS 2002).

Species in *Boronia* are considered difficult to germinate as their seeds possess physical and physiological dormancies allowing persistence in the soil seedbank (Auld 2001; Mackenzie *et al.* 2016, Ma *et al.* 2018). These dormancies are overcome by various ecological processes such as heat shock, smoke or the combination of both which then allows the now non-dormant seed to await advantageous environmental cues to stimulate germination (Mackenzie *et al.* 2016, Ma *et al.* 2018). Species in *Boronia* section *Valvatae* have been found to germinate faster and more abundantly only at spring and summer temperatures after treatment with heat shock and smoke, with little to no germination at low temperatures, indicating faster seedling emergence following spring and summer fires and a considerable delay in germination following autumn and winter fires (Mackenzie *et al.* 2016). It is highly likely that *B. hapalophylla*

NSW Threatened Species Scientific Committee

responds similarly, with observations of large germination events in wild populations following the 2019/20 fires supporting this (G. Phillips pers. obs. November 2021).

Seed viability in *Boronia* is typically high, with fill rates for mature seeds recorded above 90% in species within section *Valvatae* and typically greater than 75–80% more broadly in the genus, translating into viability rates in many *Boronia* species of 95% or higher (Mackenzie *et al.* 2016, Ma *et al.* 2018). Records of lower fill rates and thus viability may be influenced by seed predation, although this is poorly studied in *Boronia* (Auld 2001). Predation after initial dispersal when seeds are most vulnerable may be reduced by the moving of seeds underground by ants and this may also affect dormancy breaking, germination and seedling emergence depending on the depth of burial, providing further buffering against stochastic effects of disturbances such as fire and the exhaustion of soil seedbanks in a single disturbance event (Hughes and Westoby 1992; Auld 2001; NSW NPWS 2002).

Threats

The NSW Scientific Committee (2004) state that “the area in which *Boronia hapalophylla* is recorded is under threat of clearing for a proposed road and other infrastructure with potential weed invasion and other degradation as a result of increased access”. However, this only concerns the northern Shannon Creek subpopulation, as it was the only one known at the time of listing. These threats have now ceased. Changes in fire regime and clearing of habitat are now recognised as potential threats to the broader population of *B. hapalophylla* (NSW OEH 2021), with high frequency fire regimes particularly noted following the 2019/20 fires that affected all three subpopulations (NSW NPWS 2022), potentially compounding previous high frequencies of burning at these sites. However, recent surveys have found all subpopulations of *B. hapalophylla* to be stable with no threats regarded as critical to the species and no evidence of continuing decline apparent (Sheringham 2021; G. Phillips pers. obs. November 2021).

Changes in fire regimes

The habitat in which *B. hapalophylla* occurs is fire prone and this is reflected in the ecology of *B. hapalophylla* (NSW NPWS 2006; Mackenzie *et al.* 2016). The species’ facultative seeding life history, short primary and secondary juvenile periods and fire-stimulated germination cues all confer a level of adaptation to fire (Auld 2001; Mackenzie *et al.* 2016). It is possible that too-frequent fire may alter the structure of the population in time, with some subpopulations already potentially seeing this shift with smaller average mature plant sizes and greater reliance on obligate seeding life histories (Sheringham 2021).

Most known subpopulations appear to undergo regular burning, with high frequency fire regimes being a key management concern in many of the NPWS managed reserves in which *B. hapalophylla* occurs. This is due to high rates of arson and fires entering from neighbouring agricultural areas (NSW NPWS 2003, 2004, 2006, 2009). Some reserves, such as Chambigne Nature Reserve, undergo significant burning at least once a decade with minor fires in between, and it is normal for the whole reserve or large sections thereof to be affected in a single fire event (NSW NPWS 2006). Fire history data in these regularly burnt sites indicate the intervals between fires to

NSW Threatened Species Scientific Committee

currently be far lower than the recommended fire-free interval of 10 years for *B. hapalophylla* (NSW BioNet 2022) and the communities it occurs in more broadly with 6 to 10-year minima (NSW NPWS 2006) (Table 2). Despite this, *B. hapalophylla* has not been recorded as undergoing decline in any of these sites to date, with populations in the most frequently burnt areas such as Yuraygir State Conservation Area and Sherwood Nature Reserve appearing stable and maintaining good health (Sheringham 2021; G. Phillips pers. obs. September 2019, November 2021). There also appears to be no correlation between frequency of burning and abundance, with subpopulations of relatively high and low population sizes found in both long unburnt and frequently burnt sites (Table 2).

Table 2 – Fire frequency data for all known sites of *Boronia hapalophylla* (drawn from NSW NPWS 2019).

Site	Vegetation community fire frequency threshold status ¹	Wildfire occurrences since 2000 ^{1,3}	Seasons of wildfire impact since 2000 ¹	Median fire interval since 2000 (years) ¹	<i>B. hapalophylla</i> Subpopulation Count ²
Flaggy Creek Nature Reserve	Vulnerable	1	2002/03	-	108
Tallawudjah Nature Reserve	Too frequently burnt	6	2002/03, 2005/06, 2007/08, 2009/10, 2014/15, 2018/19	3	131
Hayards Crossing Vacant Crown land	Long unburnt	0	-	-	1457
McGills Road VCA	Vulnerable	2	2014/15, 2019/20	5	40
Orara Way Crown Land	Within threshold	1	2002/03	-	14
'Bull Paddock', Orara River	Vulnerable	1	2019/20	-	unknown
Chambigne Nature Reserve	Vulnerable	4	2002/03, 2011/12, 2015/16, 2020/21	5	241
Shannon Creek Dam	Vulnerable	5	2008/09, 2013/14, 2014/15, 2015/16, 2019/20	2.5	658
Sherwood Nature Reserve	Within threshold/Vulnerable	6	2000/01, 2002/03, 2005/06, 2012/13, 2013/14, 2018/19	3	8640
Conglomerate State Forest	Long unburnt	0	-	-	546
Dundoo Creek	Within threshold	0	-	-	unknown

NSW Threatened Species Scientific Committee

Newfoundland State Forest	Too frequently burnt	4	2001/02, 2013/14, 2017/19, 2019/20	4	39
Yuraygir State Conservation Area	Too frequently burnt/vulnerable	5	2001/02, 2006/07, 2013/14, 2017/18, 2019/20	4.5	5337

¹Drawn from NPWS Firetools Cloud data (NSW NPWS 2019)

²Census data from Sheringham (*in litt.* April 2022)

³Year 2000 chosen as cut-off date due to increased knowledge gaps prior to this time

Given the fire history of the region, including the 2019/20 fire season in which several fires burnt in the range of *Boronia hapalophylla* (NSW NPWS 2022), it remains highly unlikely that a single future fire event would affect all locations in unison (Sheringham 2021). There appears to be a mosaic of burnt and unburnt areas across the species' distribution adequate to maintain current populations (Sheringham 2021). The Shannon Creek, Yuraygir and Orara Valley subpopulations are separated by tracts of land cleared for agriculture, major road and rail corridors and villages such as Glenreagh and Coutts Crossing. Different subpopulations are therefore unlikely to experience the same fire histories or impacts, as fire cause, spread and frequency have differed greatly in each to date and will likely continue to do so (NSW NPWS 2004, 2006, 2009). In some areas such as the Waihou Plateau in Sherwood Nature Reserve, topography also acts as a natural barrier to widespread fire (NSW NPWS 2009), providing additional buffering to the impacts of fire across the population.

Clearing of habitat and fragmentation

The Shannon Creek subpopulation of *B. hapalophylla* was considered at risk from clearing for infrastructure projects related with the Shannon Creek Dam when initially described and listed as a threatened species in 2004 (Duretto *et al.* 2004; NSW Scientific Committee 2004). The provision of an access road and infrastructure for the dam resulted in the clearing of 1.2 ha of habitat and 100–200 plants of *B. hapalophylla* when the dam was constructed (Greenloaning 2004). Given the subsequent discovery of substantially more plants away from Shannon Creek, this clearing is now considered minor in impact with less than 2% of the current known population affected. The Shannon Creek subpopulation is currently considered stable since the construction of the dam was completed (J. Edwards *in litt.* April 2022) and decline from the clearing has now ceased apart from regular road and easement maintenance in the cleared corridors (J. Edwards *in litt.* September 2022). The remaining plants are within compensatory habitat set aside as a conservation reserve (McPherson 2008).

Clearing of habitat in the southern Clarence Valley for agriculture and quarrying may pose an increasing threat to some subpopulations of *B. hapalophylla* in future, but this activity appears to be localised in nature and unlikely to impact the major subpopulations that occur in conservation reserves (Sheringham 2021). Given the species' preference for ridgetops and slopes around outcropping sandstone and infertile sands, its habitat appears inconsistent with the most at-risk sites for agricultural clearing in areas of active development (P. Sheringham *in litt.* June 2022). The Orara Valley subpopulation may come under increasing pressure through rural subdivisions and hobby farm establishment, but this threat is likely to be minimal on stands of *B. hapalophylla* in the area with road and fence construction the most likely

NSW Threatened Species Scientific Committee

impacts as opposed to outright clearing of habitat (P. Sheringham *in litt.* June 2022). Other highly localised activities, such as track creation and maintenance, recreational visitation and land use, and illegal drug cultivation have been recorded at some sites, however these are deemed to be minor with a negligible impact on the species to date with only individual plants affected in places (Sheringham 2021; P. Sheringham *in litt.* April 2022).

Habitat fragmentation resulting from clearing is mentioned as a threat to *B. hapalophylla* by NSW OEH (2021). This is deemed to be a low risk given the preferred habitat, with its low productivity, has low incidences of clearing to date due to the infertile geology (P. Sheringham *in litt.* June 2022). This has resulted in large, contiguous subpopulations being protected on conservation estate (P. Sheringham *in litt.* June 2022), lowering the potential for impact from of future clearing. It is likely that *B. hapalophylla* has historically had a level of fragmentation similar to its modern distribution on the higher sandstone plateaus and ridges in the region, and so fragmentation is not regarded as a cause of continuing decline and is only a possible future threat to the species (P. Sheringham *in litt.* June 2022).

A large stand of *B. hapalophylla* found since 2019/20 occurs on a small plateau east of Sherwood Nature Reserve in Conglomerate State Forest. This forest is subject to intense logging in some areas (G. Phillips pers. obs. November 2021). The plateau containing the stand of *B. hapalophylla* was protected as 'High Conservation Value Old Growth' forest (Aspden 2011) prior to the discovery of the *B. hapalophylla* stand and is also considered unsuitable for logging (Sheringham 2021). This means that while track maintenance activities may impact some *B. hapalophylla* plants in the future, logging in this area is likely to be of minimal impact on the species.

Assessment against IUCN Red List criteria

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

Criterion A *Population Size reduction*

Assessment Outcome: Criterion not met.

Justification: There is no evidence of current or historical population reduction. Given a maximum three generation timespan of 12–15 years, a population size reduction in *B. hapalophylla* of at least 50% for reversible and ceased causes (A1) or 30% for irreversible or continuing causes (A2, A3 and A4) has not been observed or is predicted to occur.

Criterion B *Geographic range*

Assessment Outcome: Criterion not met.

Justification: *Boronia hapalophylla* is endemic to the southern Clarence Valley and has a highly restricted geographic distribution. The Extent of Occurrence (EOO) of *B. hapalophylla* has been calculated as 572 km², which meets the threshold for listing as Endangered. The Area of Occupancy has been calculated as 208 km², also meeting

NSW Threatened Species Scientific Committee

the threshold for 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: Subcriterion met for Endangered due to having three threat-defined locations.

Justification: *Boronia hapalophylla* is found at three threat-defined locations when considering the most serious plausible threat of changed fire regimes.

Boronia hapalophylla is not considered severely fragmented as most individuals are found in large, non-isolated subpopulations and all subpopulations are 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: Subcriterion not met.

Justification: Continuing decline is not currently evident in the known subpopulations of *Boronia hapalophylla* despite plausible threats being present. The previous removal of a portion of the Shannon Creek subpopulation for the construction of an access road and infrastructure to support the construction of Shannon Creek Dam resulted in some localised population loss, however decline is no longer continuing, and this subpopulation is currently regarded as stable (J. Edwards *in litt.* April 2022) and the remaining plants are protected in a conservation reserve (McPherson 2008). *B. hapalophylla* appears to be highly adapted to persist in fire prone environments and recent surveys have found numerous seedlings already producing seed less than two years post fire (Sheringham 2021; G. Phillips pers. obs. November 2021). A number of subpopulations are subject to high fire frequencies shorter than the recommended fire-free threshold for the species of 10 years (NSW NPWS 2019; NSW BioNet 2022) and demographic shifts toward smaller plants and obligate seeding life strategies (Sheringham 2021) may be resulting from this. These stands remain in good health though and are reported as stable with no decline apparent post-fire and an appropriate mosaic of burnt and unburnt habitat being maintained (Sheringham 2021). Clearing for rural development, agriculture, quarries, roads, tracks and forestry operations and the fragmentation these activities may cause are also plausible localised threats. However, the large proportion of *B. hapalophylla* in conservation reserves and protected areas and the fact that core habitat is largely not conducive to clearing means that clearing is not regarded as contributing to continuing decline except in highly localised instances on individual plants (Sheringham 2021; P. Sheringham *in litt.* June 2022). Given this, no observed, estimated, inferred or suspected decline in Extent of Occurrence, Area of Occupancy, extent and/or quality of habitat, number of locations or subpopulations or number of mature individuals is yet

NSW Threatened Species Scientific Committee

evident and future declines resulting from identified threats are only regarded as plausible, not satisfying the definition for continuing decline (IUCN 2022).

c) Extreme fluctuations.

Assessment Outcome: Subcriterion not met.

Justification: *Boronia hapalophylla* is a moderately long-lived shrub and is unlikely to undergo extreme fluctuations.

Criterion C Small population size and decline

Assessment Outcome: Criterion not met.

Justification: The current estimated population for *B. hapalophylla* is at least 17,780 with the likelihood of many more plants existing in areas yet unsurveyed (Sheringham 2021; P. Sheringham *in litt.* April 2022), exceeding the threshold for Vulnerable.

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

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

Assessment Outcome: Subcriterion not met.

Justification: There is little evidence that continuing decline in mature individuals is occurring, with all subpopulations currently regarded as stable (Sheringham 2021; J. Edwards *in litt.* April 2022).

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

Assessment Outcome: Subcriterion not met.

Justification: There is little evidence that continuing decline in mature individuals is occurring, with all subpopulations currently regarded as stable (Sheringham 2021; J. Edwards *in litt.* April 2022).

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

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

Assessment Outcome: Subcriterion not met.

Justification: Two of three known subpopulations have >1000 mature individuals (Sheringham *in litt.* April 2022).

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

Assessment Outcome: Subcriterion not met.

Justification: *Boronia hapalophylla* has a spread of mature individuals across subpopulations, with the largest subpopulation (Orara Valley) possessing c. 61% of known mature individuals.

NSW Threatened Species Scientific Committee

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Subcriterion not met.

Justification: *Boronia hapalophylla* is a moderately long-lived shrub and is unlikely to undergo extreme fluctuations.

Criterion D Very small or restricted population

Assessment Outcome: Criterion not met.

Justification: *Boronia hapalophylla* is currently known to have a population of at least 17,780 mature individuals.

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: *Boronia hapalophylla* is currently known to have a population of at least 17,780 mature individuals.

- D2. Restricted area of occupancy (typically <20 km²) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: Criterion not met.

Justification: *Boronia hapalophylla* occurs at three threat-defined locations however it also has an estimated AOO of 208 km² and all identified plausible future threats are likely to be localised in nature and would likely not rapidly drive the species to extinction in a very short time across its full distribution.

Criterion E Quantitative Analysis

Assessment Outcome: Data deficient.

Justification: Currently there is not enough data to undertake a quantitative analysis to determine the extinction probability of *B. hapalophylla*.

Conservation and Management Actions

Boronia hapalophylla 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. *Boronia hapalophylla* sits within the Keep-watch management stream of the SoS program.

Activities to assist this species currently recommended by the SoS program (NSW OEH 2021) include:

NSW Threatened Species Scientific Committee

Habitat loss, disturbance and modification

- Protection of areas of known and potential habitat from clearing or development.
- Implementation of suitable fire regimes for the habitat in which *B. hapalophylla* occurs in line with findings from ecological research.
- Ensure stock grazing in known subpopulations is minimized so as not to adversely impact the species.

Ex situ conservation

- Maintain viable *ex situ* seedbank collections from across the species' known range

Survey and Monitoring

- Report any new records of *B. hapalophylla* to relevant authorities.

Information and Research

- Research into ecological requirements of the species, particularly responses to fire and required fire regimes.
- Provide advice on the requirements and known locations of *B. hapalophylla* to planning authorities to allow adequate assessment of the impacts of proposed development and activities.

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NSW Threatened Species Scientific Committee

APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria

The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:

Boronia hapalophylla was found to be Least Concern and thus ineligible for listing as a threatened species as none of the Clauses were met.

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: Clause not met

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,

NSW Threatened Species Scientific Committee

	(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: Clause not met

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.

NSW Threatened Species Scientific Committee

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 not met

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.
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APPENDIX 2
Distribution Map

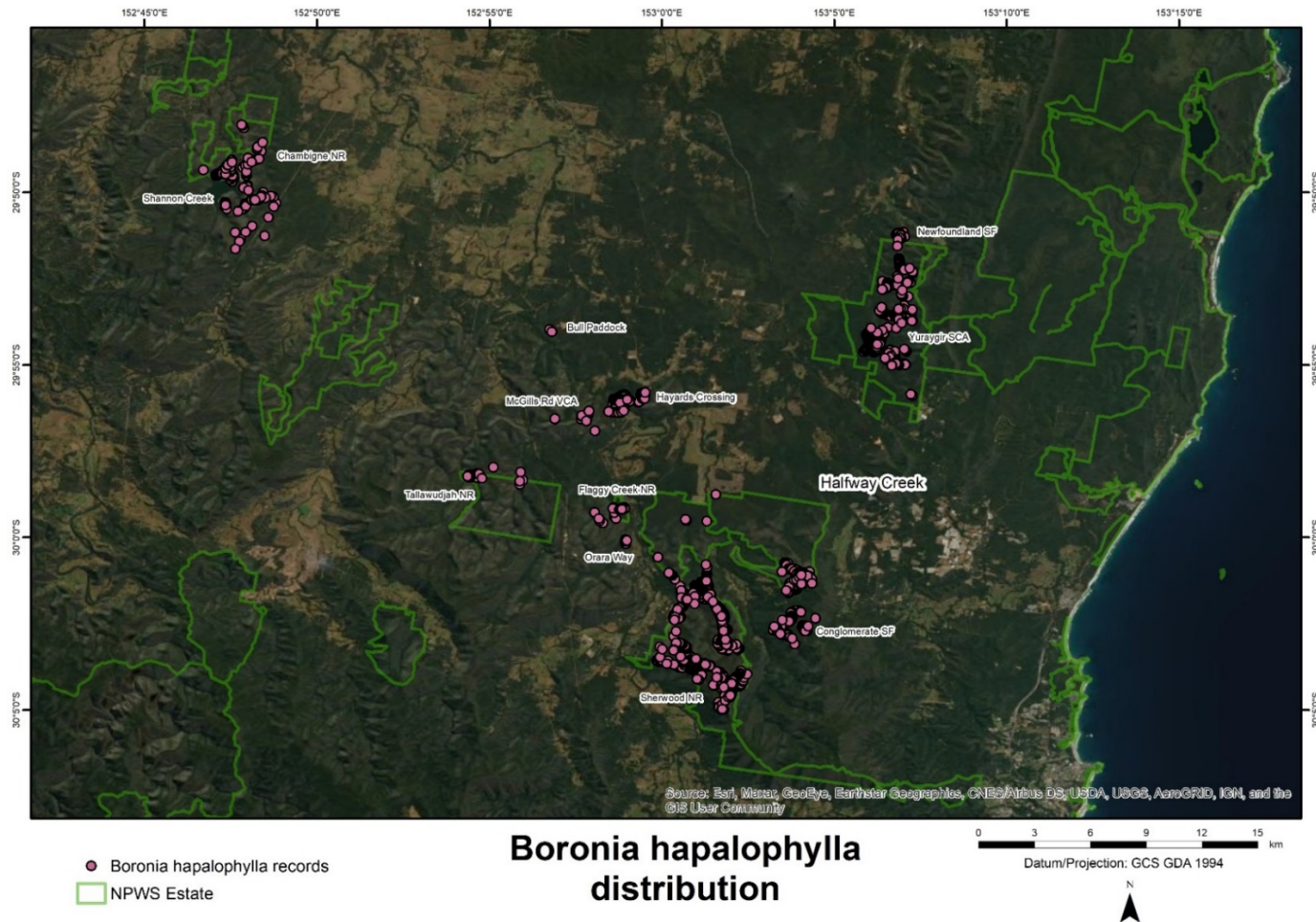


Figure 1 – Distribution map of *Boronia hapalophylla*. Note that no data points are available for the unsurveyed Dundoo Creek site near Halfway Creek.