

NSW Threatened Species Scientific Committee

Conservation Assessment of *Hibbertia superans* Toelken (Dilleniaceae)

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Hibbertia superans Toelken (Dilleniaceae)

Distribution: Endemic to the Greater Sydney region of NSW

Current EPBC Act Status: Not listed

Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act: Endangered

No change to listing.

Summary of Conservation Assessment

Hibbertia superans was found to be eligible for listing as Endangered under IUCN Red List Criteria A2b + A4b + B1ab(ii,iii,v) + B2ab(ii,iii,v) + C1 + C2a(ii).

The main reasons for this species being eligible are: (1) a large population reduction of up to 77% of mature individuals has been estimated as a result of clearing for residential development, adverse fire regimes, habitat degradation from disturbance, and competition from weeds over a two to three generation timespan; (2) the species has a highly restricted geographic distribution with an area of occupancy of 140 km² and an extent of occurrence of 1,048 km²; (3) the species is considered to be severely fragmented; (4) there is an estimated and inferred continuing decline in AOO, habitat quality and mature individuals from vegetation clearing for residential and rural residential development, adverse fire regimes, habitat degradation from human activities, and competition from weeds; (5) the estimated total number of mature individuals of the species is low (c. 750); and (6) Most mature individuals exist within a single subpopulation, with the largest containing approximately 90% of known mature plants.

Description and Taxonomy

Hibbertia superans (family Dilleniaceae) was originally included within *Pleuranda sericea* in 1817, and was moved into genus *Hibbertia* in 1863. *Hibbertia sericea* was subsequently found to consist of a species complex, which is now recognised as twelve species (including *H. superans*) and three subspecies (Toelken 2000). In the 2001 Final Determination (NSW Scientific Committee 2001) an endangered population previously known as *H. incana* was included in the assessment, however this species is now known as *H. crinita* (PlantNET 2022a) and is not included in this assessment.

PlantNET (2022b) describes *Hibbertia superans* as “Low spreading shrubs with few to many, weak twisting branches to 40 cm long. Leaves linear, rarely linear-elliptic, (5.6-7.5-10(-12.3) mm long, 0.9-1.2(-1.4) mm wide; apex acuminate to acute; base gradually tapering to petiole, petiole to 0.5 mm long; margins revolute, appearing thickened. Young branches and leaves covered with long silky hairs over a dense indumentum of short stiff hairs. Longer hairs often wearing off with age. Some scattered stellate hairs also present, particularly on the younger branches and the lower surface of leaves. Flowers single; sessile or shortly pedicellate; terminal on main

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branches (or rarely on short shoots); bracts linear, 8.3-9.5 mm long, 1.0-1.3 mm wide, leaf-like with distinct central vein, villous sometimes becoming tomentose above and below. Calyx not accrescent; outer calyx lobes linear-lanceolate, acute, with slender central vein, villous-tomentose, mostly 7.5-9 mm long and 1.4-1.7 mm wide, much longer than inner lobes; inner calyx lobes oblong-elliptic to obovate, obtuse to rounded, 4.2-6.5(-7.6) x 1.9-2.7 mm, outside villous over more or less appressed pubescent, inside rarely with a few appressed hairs towards the apex. Petals broadly obovate, 5.5-6.7 mm long, emarginate. Stamens 6-9, subequal; filaments basally connate, but often some more than others; anthers narrowly oblong, (1.4-)1.6-1.8 mm long, dehiscent mainly by lateral slits. Pistils 2; ovaries laterally compressed, each with 4 ovules; style from outer apex of ovary, curved outwards and around the cluster of stamens to end at the apex of the outer anthers. Fruit villous with very dense erect simple hairs. Seeds oblong-obovoid, often oblique, 1.5-1.7 x 1.1-1.4 mm, fleshy aril expanding into a scarcely lobed sheath adpressed to the base of seed, often to one side of base of seed." *Hibbertia superans* has been recorded up to 40cm high and spreading up to 1 m wide (R. Miller *in litt.* December 2022).

Distribution and Abundance

Hibbertia superans is endemic to the Greater Sydney region of NSW. It mainly occurs in the northwest Sydney region between Baulkham Hills and Wisemans Ferry. It has also been recorded in very small numbers in the Berowra Valley, Belrose, North Turramurra, Dural and Manly, and in the lower Blue Mountains between Blaxland and Faulconbridge. It was previously thought to occur at a disjunct occurrence near Mt Boss (inland from Kempsey) on the mid north coast of NSW (NSW Scientific Committee 2001), but this record now belongs to a separate taxon and is not included in this assessment (H. Toelken *in litt.* December 2022).

In this conservation assessment a site is defined as a geographically distinct area that is separated from another site by at least 250 metres, and may contain one or more occurrences, or records, of *Hibbertia superans*. Each occurrence may contain one or more individuals.

The current distribution estimate is based on 845 unique records compiled from NSW Bionet Atlas, Atlas of Living Australia, herbarium specimens, and records from a survey of nine sites in 2021 (Miller 2022).

Subpopulations

There are eleven subpopulations of *Hibbertia superans* based on a geographic separation of >2.5 km between clusters of sites. Sites are separated by cleared and developed land, restricting gene flow from either pollination or seed dispersal (Table 1). Cleared and developed land is likely to act as an effective barrier to all but extremely rare episodes of genetic exchange, which defines a subpopulation as per IUCN (2022). Native bees, which are considered the most effective pollinator of zygomorphic *Hibbertia* species, forage over much shorter distances than honeybees, 700 m to over 1000 m (Greenleaf *et al.* 2007; Smith *et al.* 2016), which is likely to make effective pollination distance within a couple of kilometres. The largest subpopulation by far is located in northwest Sydney from Castle Hill to Glenorie, encompassing over 30 sites. All other subpopulations are very small. The three Blue Mountains sites are separated by 5-7 kms of national park land and if unknown occurrences of *H. superans* exist, then the lower mountain occurrences could be one or two subpopulations.

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Table 1. *Hibbertia superans* subpopulations

Area
Castle Hill to Glenorie
Maroota 1
Maroota 2
Maroota 3
North Rocks and Baulkham Hills
Berowra Valley
Ku-Ring-Gai Chase NP
Faulconbridge
Winmalee
Mount Riverview

Population Size and Trends

The total population size of *Hibbertia superans* is estimated to be approximately 750 mature individuals. Historically the species has been recorded from approximately 45 sites, with eleven sites with over 100 individuals and much smaller numbers at the other sites. All record counts are assumed to be of mature individuals as without flowers this species is very difficult to find and identify. The current largest site of *H. superans* is at Cattai Creek Drive, Kellyville, where 277 plants were recorded in 2020 (WSP 2020). An approved development application for residential housing at this site will result in the extirpation of 77 individuals (WSP 2020). The second largest site is near Heath Rd and Saltwater Crescent, Kellyville, where there are currently 190 individuals. The number of individuals at this site declined from 650 in 2008 to 480 in 2019 (BioNet 2023), and then to 190 in 2022 after vegetation was cleared for a housing development (ArcGIS Online 2022).

Hibbertia superans has undergone a large reduction in population size since the late 1990s and early 2000s. Population trend data is available for 92% of the population recorded in the late 1990s (3,092 individuals at 16 sites) and early 2000s (3,380 individuals at 45 sites). This large subset of the population has declined 77% to 722 individuals (2-3 generations) as a result of land clearing for residential and rural-residential development, adverse fire regimes, habitat degradation from human disturbance and competition from weeds. The population trajectory of the other 8% of the population (288 individuals) is unknown but it is reasonable to infer a similar decline in the presence of the current known ongoing threats.

Hibbertia superans is found on a mixture of land tenures: 23 sites (>50% of sites) are on private land or part on private or unreserved Crown land, 11 are on, or part on, Council or Crown reserves, four are in a NPWS reserve, two are on Aboriginal Land Council land and one in State Forest.

Extent of Occurrence and Area of Occupancy

The Extent of Occurrence (EOO) is 1,048 km² and the Area of Occupancy (AOO) is 140 km². 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). The AOO is based on 2 x 2 km grid cells, the scale recommended for assessing area of occupancy by IUCN (2022). The EOO and AOO

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were calculated using ArcGIS (Esri 2015) and encompasses the entire known past and extant distribution of the species. The AOO may be an underestimate as there has been no systematic survey effort for *Hibbertia superans* across its distribution so there may be individuals that have not been recorded.

Number of Locations

The number of threat-defined locations of *Hibbertia superans*, when the most serious plausible threats of vegetation clearing for development and adverse fire regimes are considered, is greater than 10. The IUCN Guidelines (2022) state that “where the most serious plausible threat is habitat loss that occurs gradually and cumulatively via many small-scale events, such as clearance of small areas for small-holder grazing, a location can be defined by the area over which the population will be eliminated or severely reduced within a single generation or three years, whichever is longer.” There are at least 28 recorded sites of *H. superans* on private or unreserved lands, and these sites are primarily small patches within the urban footprint of Sydney including the North West Priority Growth Area earmarked for increased residential development by 2036 (DPE 2017). Therefore, the threat of small-scale development affecting many of these sites separately across the next 12 years (1 generation being 7-12 years) is high, and so these sites can be treated as a single threat-defined location.

Other sites that are in reserved lands (including NPWS estate, Council and Crown conservation reserves, and private land under conservation agreement) are not considered at threat of development, and the threat of adverse fire regimes is considered the most serious plausible threat at these sites. Many of these remaining sites are in small, fragmented remnants within the urban matrix or on the peri-urban fringe, and so fire regimes are likely to greatly differ across them, and single fire events are unlikely to affect multiple sites. This means that a minimum of 10 threat-defined locations can be defined using adverse fire regimes for these sites, resulting in the minimum number of threat-defined locations for *Hibbertia superans* being 11.

Cultural significance

Hibbertia superans occurs on the traditional lands of the Eora, Dharug and Gundungarra people who have a strong and ongoing cultural connection with their traditional lands and waters (AIATSIS 2022). Aboriginal Peoples have cared for Country for tens of thousands of years (Bowler *et al.* 2003; Clarkson *et al.* 2017). In northern NSW *Hibbertia scandens* was used by the Yaegl people as a medicinal plant to treat sores and rashes (Packer *et al.* 2012), and *H. superans* may have had similar cultural uses.

Ecology

Hibbertia superans is a small spreading perennial shrub with soft-woody branches and distinctive bright yellow flowers (Toelken 2000). *Hibbertia superans* flowers from July – December (PlantNET 2022b). In the Sydney region it occurs in Dry Sclerophyll Forest on sandstone ridgetops, often close to the shale/sandstone transition (James 2012; PlantNET 2022b; Toelken 2000). *Hibbertia superans* is often associated with canopy species such as *Allocasuarina littoralis*, *Angophora bakeri*, *A. hispida*, *Corymbia gummifera*, *C. eximia*, *Eucalyptus piperita*, *E. racemosa*, *E. cryptica*, *E. squamosa* and a large diversity of understory shrubs including other threatened flora such as *Acacia bynoeana*, *Darwinia biflora*, *Epacris purpurascens* var. *purpurascens*,

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Leucopogon fletcheri subsp. *fletcheri*, *Persoonia hirsuta* and *Pimelea curviflora* var. *curviflora* (NSW Scientific Committee 2001; Miller 2022). *Hibbertia superans* has been recorded in two Sydney Basin Bioregion threatened ecological communities: Sydney Turpentine-Ironbark Forest and Duffy's Forest Ecological Community. It had also been recorded close to but not in the mapped distribution of Shale/Sandstone Transition Forest (DPE Threatened Ecological Communities for Greater Sydney spatial layer).

Flowers first appear from resprouting material about two years after fire (DPE 2022b). The time to first flowering of seedlings is unknown. The fruit is dehiscent, and the seed has a fleshy aril which encourages ant dispersal (Benson and MacDougall 1995). The average lifespan of another species of *Hibbertia*, *H. tenuis* is estimated to be 10–20 years (TSSC 2010) and this estimate is used in this *H. superans* assessment as it is consistent with the large declines in individuals recorded 20 years after fire. Using this information, the generation time for *H. superans* is inferred to be 7-12 years, with three generations being 21-36 years.

The germination requirements of *Hibbertia* species are complex and vary between species. Seed dormancy is imposed by the seed coat as well as by the embryo (Ralph 2011; Hidayati *et al.* 2012). In many *Hibbertia* species germination is increased by scarification and/or smoke water (Dixon *et al.* 1995; Schatral 1996; Schatral *et al.* 1997; Allan *et al.* 2004). Variation in dormancy length among individual seeds may result in naturally staggered germination over several years (Schatral *et al.* 1997; Ralph 2011; Hidayati *et al.* 2012). The longevity of *H. superans* seeds in the seedbank is unknown, however *Hibbertia* species are thought to have a persistent seedbank (TSSC 2016; Cuneo *et al.* 2018).

Fire Ecology

Hibbertia superans is a facultative seeder that is well-adapted to repeated fire in the landscape. It recovers well after fire mostly from re-growth from rootstock (James 2012). Seed germination may require high fire intensity (James 2012), as it does in the small, Critically Endangered western Sydney *Hibbertia spanantha* (Toelken and Robinson 2015). Populations fluctuate with large numbers recorded 2-4 years after fire and falling as vegetation increases in height and density (James 2012).

The majority of *Hibbertia superans* sites are long unburnt and are likely to remain as such given proximity to residential and rural-residential areas. In the absence of fire (recommended maximum interval of 25 years; DPE 2022b), the low, spreading *Hibbertia superans* is outcompeted by taller and larger understory shrub and trees species such as *Pittosporum undulatum*, *Allocasuarina littoralis*, *Kunzea ambigua*, *Syncarpia glomulifera* (Miller 2022). In long-unburnt sites, a dense detritus layer comprised of leaf litter, fallen branches and twigs smothers *H. superans* and suppresses seedling germination (Miller 2022). Dense, long unburnt vegetation becomes unsuitable habitat for *H. superans* and if a no-fire regime is maintained the species is unlikely to persist in an area, or if it has disappeared, is unlikely to recover as the seed bank, while persistent, has reduced viability over time (Miller 2022).

The recommended fire interval for *Hibbertia superans* is not less than seven years (NSW Rural Fire Service 2013).

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Pollination, seed dispersal and gene flow

Hibbertia spp. have been reported to be pollinated by native bees given their poricidal anthers, with other flower visitors of note being honeybees *Apis mellifera*, pollen-seeking flies, and pollen consuming beetles (Armstrong 1979; Tucker & Bernhardt 2000). *Hibbertia superans* has zygomorphic flowers, where the stamens are aggregated in one side of the flower, and it is thought that native bees are the most effective pollinators of such flowers (Tucker and Bernhardt 2000). Honeybees have the potential to pollinate over long distances of up to several kilometres, however, mostly forage closer to a hive, influenced by the locations of suitable foraging patches (Beekman and Ratnieks 2001). Native bees forage over much shorter distances. A study of three native bees found them to forage up to 700 m from the hive (Smith *et al.* 2016). However, native bees may be able to pollinate over longer distances as a review of studies of foraging distance of 62 bee species found that body size predicts foraging distance and the largest bees foraged over more than 1 km distance (Greenleaf *et al.* 2007). Beetles have the potential to pollinate plants separated by hundreds of metres to kilometres (Hodek *et al.* 1993; Rink and Sinch 2006; Hedin *et al.* 2007).

The seeds of *Hibbertia* are thought to be dispersed via water and by ants which are attracted to the fleshy aril (Rice and Westoby 1981). In sclerophyll vegetation near Sydney, ants have been found to disperse seeds mostly less than 2 m and rarely over 4 m (Westoby *et al.* 1991). If ants and water are the dispersal agents for this species, then it is highly unlikely that seeds are transported far from any cluster of individuals.

Threats

Hibbertia superans is threatened by vegetation clearing for residential and rural-residential development, adverse fire regimes, habitat degradation from human activity, competition from weeds, and disease (Miller 2022; NSW Scientific Committee 2001).

Vegetation clearing for residential and rural-residential development

Hibbertia superans has been severely affected by residential and rural-residential development over the last few decades with most of its ridgetop habitat now developed (Miller 2022). The small remaining bushland habitat areas that have not been cleared for development face many pressures as a result of adjacent development and substantial human activity. 'Clearing of Native Vegetation' is listed as a key threatening process under the *Biodiversity Conservation Act 2016*.

Many old records from the northwest Sydney suburbs indicate that former sites of *Hibbertia superans* are now located under housing developments. In recent years, a housing development adjacent to Cattai Creek cleared 289 of 479 individuals (61%), once the largest known stand of *Hibbertia superans*. An approved housing development on Cattai Creek is also planned to clear 77 of 277 individuals in the near future. At Kenthurst Park, the Hills Shire is currently upgrading facilities in the southern portion of the park, which may negatively affect *H. superans*. Other proposed developments in Ellerman Park, Belrose and Maroota may also affect small stands of this species.

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Adverse Fire Regimes

The threat of adverse fire regimes, incorporating too frequent fire, too severe fire, and/or too infrequent fire is inferred to be a major driver of decline in *Hibbertia superans*. The species exists in small fragments primarily in an urban matrix which can experience highly variable fire regimes, ranging from very frequent due to high rates of arson and hazard reduction burning (Auld and Scott 1995; Stenhouse 2004), to very low due to heavy fire suppression efforts (Gill and Williams 1996; Tresize *et al.* 2020), and can even rapidly switch from one extreme to the other with urban expansion (Syphard *et al.* 2007). This means that the regime that best suits persistence of species such as *H. superans* can easily be altered due to urban influences, causing decline in the quality of habitat and number of mature individuals of the species. '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 *Biodiversity Conservation Act 2016* and 'Fire regimes that cause declines in biodiversity' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Too frequent and/or too severe fire can cause decline in the population of *Hibbertia superans* if the minimum recommended fire-free threshold of seven years is not maintained (NSW Rural Fire Service 2013), or high severity fire were to affect key sites. A number of *Hibbertia* species are known to favour less-burnt areas, with fire return intervals more frequent than 10 years having significantly lower abundances of standing plants than those burnt at 20+ year cycles (Watson and Wardell-Johnson 2008; Tuner *et al.* 2020). It is possible that *H. superans* also responds in this way given significant decline has been noted in sites which have been burnt at mean intervals of less than 10 years (Miller 2022). Given many of the areas of *H. superans* habitat are long-unburnt and therefore may have reduced soil seedbanks, and that previous burning regimes likely consisted of lower-intensity burning regimes, repeated incidences of fire could also kill standing plants and rapidly exhaust the remaining soil seedbank at a given site. Additionally, other *Hibbertia* species (e.g., *H. calycina*; Turner *et al.* 2020) have been locally extirpated following single occurrences of high severity fire which eliminates resprouting individuals and the soil seedbank, and only persist with lower severity fire. This means that both increased frequency, or increased severity of fire are inferred to reduce the number of mature individuals of *H. superans* when they occur.

Long term absence of fire at *Hibbertia superans* sites is also inferred to be a cause of decline (Miller 2022), as has been found in other species that have fire-related germination cues and that are found in isolated remnants such as *Hibbertia tenuis* (Tresize *et al.* 2020). Most of the largest recorded patches of *H. superans* are long unburnt (18 – 20+ years) and large declines in standing plants (40-95%) have been recorded since the previous fire. This includes sites at Cattai Creek Drive, Bill Woods Reserve, Cadwell Road, Porters Road, Clarke Road, Millars Road and Kemp Place, Robson Road, and Bannerman Road.

At long unburnt bushland sites in the Sydney Basin, the native vegetation becomes denser and taller, outcompeting the low, spreading *Hibbertia superans* and suppressing seedling germination (Miller 2022). Without fire and soil disturbance to break seed dormancy and open up the understory to allow seedlings to grow and

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mature (e.g., Tresize *et al.* 2020), *H. superans* is unlikely to be able to persist and recolonise these sites. Where *H. superans* sites are on private land or in reserves surrounded by urban development, hazard reduction burning is logistically difficult and seldom conducted. While localised arson incidents are more common in these areas, wildfire risk is low and remnants fragmented by urbanisation can see suppression of any fire favoured over ecologically sensitive burning (Gill and Williams 1996; Tresize *et al.* 2020). Isolation of bushland remnants in the greater Sydney area also prevents species migrating to adjacent areas where a different disturbance regime may provide suitable habitat. In Sydney peri-urban bushland remnants, plant species diversity driven by shrub species richness has been found to increase with fire frequency (Pendall *et al.* 2022) or mature understory clearing (V. O'Donovan pers. comm. December 2022).

While the maturation of the bush is a natural landscape process, with larger shrubs often outcompeting smaller ground covering plants like *Hibbertia superans* as plants age, long-term absence of fire in the Sydney Basin bushland is likely a relatively recent phenomenon because of fragmentation and isolation of remnants from increasing urbanisation. Traditional Owners used fire to manage the landscape of the Sydney Basin for thousands of years and are likely responsible for an elevated fire frequency in this landscape of lower severity fire (Black *et al.* 2007; Mooney *et al.* 2007). The historic peak fire frequency was about eight episodes per century (Mooney *et al.* 2007). No apparent change in fire history occurred during the transition between Aboriginal custodianship and the European occupation of Australia until the latter part of the 20th century, when the fire frequency and intensity/severity dramatically increased in some areas because of anthropogenic climate change in combination with changing land use (Constantine 2022), yet in other areas has declined as a result of fragmentation.

The recommended maximum fire interval for *Hibbertia superans* is 25 years (DPE 2022b), however the declines recorded for *H. superans* at sites burnt 18-20 years ago suggest that a shorter maximum fire interval may be needed to prevent larger native shrubs and trees outcompeting this species. This shift in vegetation composition means that lowered frequencies of appropriate fire are observed to be causing decline in the habitat quality of *H. superans*, and the number of mature individuals is inferred to decline as a result if long-unburnt vegetation remains in such a state.

Habitat degradation from human activities.

The proximity of the majority of *Hibbertia superans* sites to residential suburbs and rural-residential properties has resulted in human activities negatively affecting the species' habitat in many ways, including by rubbish dumping, weed invasion, property maintenance, nutrification from urban runoff, road and utility easement maintenance and high levels of recreation use (Miller 2022; E Roper pers. comm. February 2023).

During 2022 surveys, household rubbish and domestic garden waste was observed dumped at several *Hibbertia superans* sites, including Porters Road, Clarke Road, Bannerman Road and Kenthurst Park (Miller 2022). The dumped refuse included lawn clippings and large quantities of the invasive weed *Eragrostis curvula* (African Lovegrass) (Miller 2022).

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Road works and adjacent vegetation management is an ongoing inferred threat to *Hibbertia superans* habitat on roadsides and utility easements. Road works and associated vegetation clearing at the Renown Road site, a narrow strip of land between a wire safety fence and a road cutting, could potentially remove the entire population (Miller 2022). At the corner of Miller Rd and Kemp Place, roadside maintenance and electricity easement works periodically affect the remnant roadside vegetation (Miller 2022).

Hibbertia superans habitat adjoining private land has been observed to be unsympathetically managed by property owners with some areas modified to lawn, frequently underscrubbed, or retained but semi-modified (Miller 2022). This has been observed adjacent to Bill Woods Reserve and at the site at the corner of Miller Road and Kemp Place (Miller 2022).

Hibbertia superans bushland sites that are public land adjacent to residential and some rural-residential areas are affected by high levels of foot and bike traffic (E. Roper pers. comm. February 2023). These effects are probably the highest in the two largest remaining clusters of *H. superans* adjacent to Cattai Creek, at Neitch Road and also Bill Woods Reserve. These negative effects will only increase with the continued development of land and growing Sydney population.

The Hawkesbury Sandstone soils of Sydney are naturally low in nutrients and the native flora, which is well adapted to growing in these soils, can be adversely affected when exposed to higher concentrations of nutrients from urban stormwater run-off and other sources (Thomson and Leishman 2004). Increases in soil nutrients in urban bushland are associated with the presence of exotic species and the decline in the diversity of native species, with the survival of native plants decreased with increasing nutrient concentrations (Thomson and Leishman 2004). Run off from adjacent land can transport weed species into bushland (Miller 2022). At the Kenthurst Park site, nitrification from run off from the adjacent sports oval has altered the vegetation structure favouring species such as *Allocasuarina littoralis*, which creates a thick ground layer of needles and dead branches that suppress ground covering vegetation (Miller 2022). At the Bannerman Road site eutrophication of the soil has occurred from intensive horticulture use of adjacent land (Miller 2022). The Millers Road site has been compromised through residential nitrified runoff, subsequent weed invasion and slashing of vegetation (Miller 2022). At the Renown Rd site, *Hibbertia superans* habitat is affected from runoff from adjacent council nursery and sports reserve (Miller 2022).

Competition from weeds

With the majority of occurrences of *Hibbertia superans* adjacent to or on residential or rural-residential land, competition from weeds, especially garden escapes, is an inferred, ongoing threat to *H. superans*. Weeds outcompete individual plants and degrade habitat. The Renown Road site is chronically infested with garden escapes including *Lonicera japonica* (Japanese Honeysuckle), *Asparagus aethiopicus* (Asparagus Fern) and *Freesia* spp. from the adjacent Bidjiwong Community Nursery, reserve, Baulkham Hills Sports Club and residences that adjoin the reserve (Miller 2022). Of concern at the Bill Woods Reserve site is the invasion of vigorous grass species over time such as *Eragrostis curvula* (African Lovegrass), *Andropogon virginicus* (Whisky Grass), *Ehrharta erecta* (Panic Veldtgrass), turf species such as

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Cenchrus clandestinus (Kikuyu), *Cynodon dactylon* (Couch) and *Stenotaphrum secundatum* (Buffalo Grass). The Iris species *Aristea ecklonii* is also considered a concern. Nutrifcation of soil from high levels of dog traffic along edges of tracks increases the further probability of weed invasion (Miller 2022). At Millers Road weed blooms were observed spilling downslope and dead plants were frequent. At Kenthurst Park, *Billardiera heterophylla* (Bluebell Creeper) is well established (Miller 2022).

Additionally, increased occurrences of fire are also known in urban reserves along with increased weed loads (Stenhouse 2004). Common grassy weeds of urban reserves, such as those found in many *Hibbertia superans* sites (Miller 2022), add substantially to the fire fuel load of the sites, especially when they die back over the summer months (Stenhouse 2004). This makes the sites more fire-prone, and increased fire then promotes the further spread of the weed species at the expense of native species (Milberg and Lamont 1994; Keighery *et al.* 2023). This means that habitat quality is inferred to be declining through weed invasion, especially where grassy weeds are in high abundance. 'Invasion and establishment of exotic vines and scramblers', 'Invasion of native plant communities by exotic perennial grasses', and 'Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants' are listed as Key Threatening Processes on the *Biodiversity Conservation Act 2016*.

Disease

Phytophthora cinnamomi is an inferred, ongoing threat to *Hibbertia superans*, because it affects other *Hibbertia* species (Weste and Ashton 1994; McDougall *et al.* 2005; Wan *et al.* 2019). *Hibbertia stricta* from south-eastern Queensland and *H. amplexicaulis* from Western Australia are known to be highly susceptible to *Phytophthora* (Weste 1994; McDougall *et al.* 2005). The rare western Sydney *H. spanantha* was found to be of intermediate susceptibility (Wan *et al.* 2019). *Phytophthora cinnamomi* was suspected to be present at the Clarke Rd site with a number of the *Xanthorrhoea* plants showing the classic symptoms and other small shrubs found dead nearby (Miller 2022). Given the location of *H. superans* sites within and adjacent to the urban environment, it is likely that *P. cinnamomi* is also present at other sites. 'Infection of native plants by *Phytophthora cinnamomi*' is listed as a Key Threatening Process on the *Biodiversity Conservation Act 2016*.

Assessment against IUCN Red List criteria

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

Criterion A *Population Size reduction*

Assessment Outcome: Endangered A2b + A4b.

Justification: *Hibbertia superans* has been estimated to have undergone a large reduction in population size since the late 1990s and early 2000s, well within a three generation timespan of 21-36 years. Population trend data is available for 92% (at 16 sites) of the population of *H. superans* recorded in the late 1990s and early 2000s (3,380 mature individuals at 45 sites). From this large subset of the population (3,092 mature individuals), there has been a 77% decline in 2-3 generations to 722 mature individuals as of 2022. This is as a result of land clearing for residential and rural-

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residential development, adverse fire regimes and human disturbance. The population trajectory of the other 8% of the population (280 individuals) is unknown but is inferred to have experienced a similar decline on the basis of known or likely active threats. The population decline of *H. superans* is also inferred to continue into the future with residential and rural-residential development prioritised for the region, including in areas of key subpopulations such as at Kellyville (DPE 2017). This means a population reduction of approximately 77% in the number of mature individuals is estimated to have occurred over the past three-generation timeframe of 21-36 years, with the causes of this reduction being irreversible and not having ceased, and this reduction is inferred to continue at similar rates into the future, meeting the threshold for Endangered.

Criterion B *Geographic range*

Assessment Outcome: Endangered B1ab(ii,iii,v) + B2ab(ii,iii,v)

Justification: *Hibbertia superans* has a highly restricted geographic distribution. The Extent of Occurrence (EOO) has been calculated as 1,048 km², meeting the threshold for Endangered. The Area of Occupancy (AOO) has been calculated as 140 km², also meeting the threshold for Endangered.

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

- a) The population or habitat is observed or inferred to be severely fragmented or there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

Assessment Outcome: Subcriterion met for severely fragmented.

Justification: When the most serious plausible threats of vegetation clearing for residential and rural-residential development, and adverse fire regimes are considered, the population of *Hibbertia superans* can be treated as a minimum of 11 threat-defined locations.

Hibbertia superans is considered severely fragmented because >50% of the total AOO consists of stands of the species that are considered smaller than is required to support a viable population and most patches are isolated within a fragmented urban matrix. 128 km² (91%) of the AOO of *H. superans* contains stands of 12 or less individuals, and much habitat is currently considered non-conducive to persistence as 88% of known sites are potentially long-unburnt or being burnt too frequently. This means that most individuals of *H. superans* are found in small and relatively isolated subpopulations with a low chance of recolonisation in the event of local extinctions, meeting the IUCN (2022) definition for severe fragmentation.

- b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals

Assessment Outcome: Subcriterion met for continuing decline estimated, inferred and projected for (ii) area of occupancy, (iii) area, extent and quality of habitat and (v) number of mature individuals.

Justification: Continuing decline is estimated and inferred in the AOO, the habitat quality, and the number of mature individuals of *Hibbertia superans*

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from vegetation clearing for residential and rural residential development, adverse fire regimes, habitat degradation from human activities and competition from weeds. There is no evidence that any of the current threats are being managed for this species, and further losses through clearing for development are likely given the prioritisation for residential development in northwest Sydney, including in areas hosting key *H. superans* subpopulations (DPE 2017). Where *H. superans* sites are on private land or in reserves surrounded by urban development, fire regimes are seldom maintained appropriately for the species, and can vary from long-unburnt to regularly burnt, with both situations causing decline in habitat and mature individuals. There is no targeted weed or anthropogenic management for this species at any site. The risk of *P. cinnamomi* infection in at urban and peri-urban sites is ever-present.

c) Extreme fluctuations.

Assessment Outcome: Data deficient

Justification: There are insufficient data to assess against this Subcriterion.

Criterion C Small population size and decline

Assessment Outcome: Endangered C1 + C2a(ii)

Justification: The estimate for the number of mature individuals is approximately 750, which meets the threshold for Endangered.

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 met at Endangered

Justification: The generation time for *Hibbertia superans* is inferred to be 7-12 years or two generations 14-24 years. It is known that 92% of the population (3,092 mature individuals at 16 sites) declined by 77% from the late 1990s and early 2000s to 2022 which meets the upper bound for the generation time estimate for *H. superans*. The level of decline in this timeframe is well above the 20% threshold needed for an Endangered outcome. Given the very large population decline estimated over two generations, it is possible that the species also meets the threshold for Critically Endangered (25% decline in 1 generation). However, the approximate two generation time interval between most data points available to measure population size trend means that the timing of decline over one generation is unknown at most sites, and for this reason the Subcriterion has not been assessed as Critically Endangered.

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

Assessment Outcome: Subcriterion met at Critically Endangered.

Justification: Continuing decline is estimated and inferred in the number of mature individuals of *Hibbertia superans* from vegetation clearing for

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residential and rural residential development, adverse fire regimes, habitat degradation from human activities, and competition from weeds. The number of mature individuals in the largest subpopulation is approximately 90% of the total population, which meets the threshold for Critically Endangered.

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 met for Vulnerable

Justification: The number of mature individuals in the largest subpopulation is 670+, located in northwest Sydney from Castle Hill to Glenorie which is ≤ 1000 but greater than 250, which meets the threshold for Vulnerable.

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

Assessment Outcome: Subcriterion met for Critically Endangered

Justification: The largest subpopulation in northwest Sydney from Castle Hill to Glenorie contains approximately 90% of the known mature individuals, meeting the threshold for Critically Endangered.

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data deficient

Justification: There are insufficient data to assess against this Subcriterion.

Criterion D Very small or restricted population

Assessment Outcome: Vulnerable D1

Justification: The number of mature individuals is estimated to be approximately 750 which meets the threshold for Vulnerable.

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: Subcriterion met for Vulnerable

Justification: The number of mature individuals is estimated to be approximately 750 which meets the threshold for Vulnerable.

- 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: Subcriterion not met.

Justification: The AOO for *Hibbertia superans* is 160 km² and it has > 10 threat-defined locations. Based on this, and the fact that on current evidence

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no threat is known that could rapidly drive the species to CR or even EX in a very short time period, criterion D2 is not met.

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 *Hibbertia superans*.

Conservation and Management Actions

Hibbertia superans is currently listed on the NSW BC Act and a conservation project has been developed by the NSW Department of Climate Change, Energy, Environment and Water 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. *Hibbertia superans* sits within the Site-managed species stream of the SoS program and the conservation project can be viewed here: <https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10403>.

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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:

Endangered under Clause 4.2 (1)(b)(2)(b) Clause 4.3 (b)(d)(e i,ii,iii) and Clause 4.4 (b)(d ii)(e i,ii (B))

Clause 4.2 – Reduction in population size of species

(Equivalent to IUCN criterion A)

Assessment Outcome: Critically Endangered under Clause 4.2 (1)(b)(2)(b)

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions (Equivalent to IUCN criterion B)

Assessment Outcome: Endangered under Clause 4.3 (b)(d)(e I,ii,iii)

The geographic distribution of the species is:			
	(a)	for critically endangered species	very highly restricted, or
	(b)	for endangered species	highly restricted, or
	(c)	for vulnerable species	moderately restricted,
and at least 2 of the following 3 conditions apply:			
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,	
	(e)	there is a projected or continuing decline in any of the following:	
		(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,

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	(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 - Low numbers of mature individuals of species and other conditions (Equivalent to IUCN criterion C)

Assessment Outcome: Endangered under Clause 4.4 (b)(d ii)(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: Vulnerable under Clause 4.5(c)

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

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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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