

NSW Threatened Species Scientific Committee

Conservation Assessment of *Hibbertia puberula* Toelken subsp. *puberula* (Dilleniaceae)

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Hibbertia puberula* Toelken subsp. *puberula

Distribution: Endemic to NSW

Current EPBC Act Status: Not listed

Current NSW BC Act Status: Listed at the species level as Endangered

Proposed listing on NSW BC Act: Endangered

Reason for change: *Hibbertia puberula* has been listed as Endangered under the BC Act, however the three subspecies that occur within NSW are now being assessed separately as each is considered to have a different conservation status.

Summary of Conservation Assessment

Hibbertia puberula Toelken subsp. *puberula* was found to be Endangered under IUCN Criterion B2ab(ii,iii,iv,v).

The reasons for the species being eligible for listing in the Endangered category are that: 1) the species has a highly restricted geographic range with an area of occupancy of 332–340 km²; 2) the population is inferred to be severely fragmented; and 3) there is an estimated and inferred continuing decline in the number of mature individuals, and the area, extent, and quality of habitat, and inferred continuing decline in the area of occupancy and number of subpopulations. These declines are due to the clearing, fragmentation, and degradation of habitat from urban development, road widening, track maintenance, and recreational vehicle use.



Hibbertia puberula subsp. *puberula* in North Turrumurra, NSW. Image: Matt Saunders.

Description and Taxonomy

Hibbertia puberula subsp. *puberula* is a subspecies in the family Dilleniaceae. The species *Hibbertia puberula* is described as a decumbent to suberect shrublet “with few wiry branches to 30 cm long, pubescent, often glabrescent, with simple long and short hairs (hairs often curved or hooked). Leaves with petiole 0.2–0.5 mm long; lamina narrowly ovate to almost linear, (1.2–)3–5.5(–8) mm long, (0.6–)0.8–1.4(–1.8) mm wide; base appearing abruptly constricted because margin strongly revolute (under surface not visible); apex more or less obtuse. Flowers single or rarely up to 3-flowered; pedicels short; bracts more or less elliptic, mostly 3–3.5(–4) mm long, leaf-like. Calyx with outer lobes ovate, more or less beaked with margin recurved distally, mostly 6–10 mm long, outer surface hispid, inner surface pubescent to silky hairy; inner calyx lobes oblong-elliptic to oblong-ovate, mostly 5–7 mm long, hispid with spreading bristles mainly along central ridge. Petals obovate, 6–8 mm long, broadly bilobed. Stamens (9–)10–14, inserted on one side of ovary, subequal; filaments fused on lower one-third. Carpels 2, slightly hairy, sometimes almost villous. Fruit puberulous with simple hairs.” (Toelken and Miller 2012; PlantNet 2023a).

Hibbertia puberula subsp. *puberula* is further described as “branches wiry to stiff-woody from woody stems. Leaf lamina mainly lanceolate. Outer calyx lobes lanceolate to ovate, 7.3–11.6 mm long, 2.5–3.8 mm wide, acute to beaked with strongly recurved margins and distinctly raised central ridge towards the apex, strigose or hirsute to rarely puberulous; inner calyx lobes broadly-elliptic to oblong-ovate, 6.9–10 mm long, 2.8–3.7 mm wide, with innermost two acute to ± cuspidate above broad membranous margins, hirsute to strigose, rarely pubescent along the central ridge becoming smaller to glabrous towards the margins. Stamens 9–18; anthers 1.3–2.1 mm long.” (Toelken and Miller 2012; PlantNet 2023b).

Hibbertia puberula subsp. *puberula* is distinguished from *H. puberula* subsp. *extensa* by having greater than seven stamens. It is distinguished from *H. puberula* subsp. *glabrescens* by its longer anthers, and the outer calyx lobes being broader when flowering, distinctly ridged toward the apex, and typically being strigose to hirsute (Toelken and Miller 2012).

Hibbertia puberula can be distinguished from other similar species, such as those in the *H. sericea* complex, by “the combination of its linear-lanceolate leaves with a central vein raised up to the leaf apex, only simple hairs, absence of a tuft of hairs between the stamens and the petals, puberulous ovary, and obloid seeds” (Toelken 2000). *Hibbertia puberula* had previously been included in *H. simulans* but is distinguished from that species by its puberulous ovary, wiry branches, and decumbent habit (Toelken 2000).

Distribution and Abundance

Hibbertia puberula subsp. *puberula* is endemic to the Sydney Basin Bioregion of New South Wales (NSW) (SEWPaC 2012). The species has a widely scattered distribution within this region, bounded roughly by Mellong in the northern Blue Mountains in the northwest, Peats Ridge on the Central Coast in the northeast, Warrimoo in the Lower Blue Mountains to the west, and Jerrawangala in the Shoalhaven to the south (Fig. A1). *Hibbertia puberula* subsp. *puberula* has been recorded as locally occasional to frequent where it occurs (Toelken and Miller 2012). The distribution of *H. puberula* subsp. *puberula* spans the traditional lands of the Darkinjung, Dharug, Kuring-gai, Tharawal, Gundungurra, and Yuin peoples (NNTT 2013; AIATIS 2023).

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Hibbertia puberula subsp. *puberula* occurs across 63–65 known subpopulations as defined by the IUCN (2024), based on a geographic separation of ≥ 1 km between clusters of occurrences, as gene flow from either pollination or seed dispersal is considered to be restricted over this distance. Native bees (Tucker and Bernhardt 2000) and pollen-consuming beetles (Keighery 1975) are considered the most effective pollinators of zygomorphic *Hibbertia* species, which have stamens inserted on only one side of the carpels. The eusocial native bee *Tetragonula carbonaria* has been found to forage to a maximum distance of approximately 700 m (Smith *et al.* 2017), although it is possible larger native bee species may forage to distances greater than 1 km (Greenleaf *et al.* 2007). As the specific beetle and bee pollinators of *H. puberula* subsp. *puberula* are unknown, generic native bee pollination distances are used to estimate the maximum gene flow distance between subpopulations, with a maximum effective pollination distance of 1 km used to determine subpopulations.

The current distribution estimate is based on 1,734 unique and cleaned records compiled from NSW BioNet Atlas, Atlas of Living Australia, herbarium specimens, and recent survey records (ALA 2023a, 2023b; ANHSIR 2023a, 2023b; BioNet 2023a, 2023b; M. Saunders pers. obs. November 2023; RBGDT 2023a, 2023b; R. Miller *in litt.* May 2024). In total, 2,722 records were excluded based on being database duplicates, location duplicates, having overly low georeference accuracy, or being likely misidentifications. For this assessment, records named only to the specific level (*i.e.*, *H. puberula*) were considered to be *H. puberula* subsp. *puberula* unless evidence was available to support their identification as another of the more range-restricted subspecies.

Extent of occurrence and area of occupancy

The extent of occurrence (EOO) was calculated at 12,941 km² and is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2024). The area of occupancy (AOO) is estimated to be 332–340 km² and was calculated using 2 x 2 km grid cells, the scale recommended by IUCN (2024). A range is provided for AOO due to the possible loss of two subpopulations to urban development. Both EOO and AOO were calculated using ArcGIS (Esri 2015).

Population size and trends

The population size of *Hibbertia puberula* subsp. *puberula* is estimated to range from 2,400 to >10,000 mature individuals. Therefore, the actual number of mature individuals is very likely to be more than 2,500. The median of these two values – 6,200 – is used in this assessment.

To determine the lower bound of the range, a figure was derived from quantifying all database records and data from reports. There are a total of 1,734 unique records representing a minimum of 3,107 individuals. Some 260 records, encompassing 736 individuals, are believed to have been cleared, leaving a minimum plausible value of 2,371 individuals, rounded up to an estimated 2,400 individuals. This figure is likely to include individuals of all age classes, not only mature individuals, as most records do not provide demographic information.

The upper bound of the range was derived through expert elicitation (A. Orme *in litt.* December 2023; R. Miller *in litt.* December 2023). However, this upper value of >10,000 considers a range of variability within the subspecies and the incomplete taxonomic review, which may result in some subpopulations being split into distinct

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entities in future (R. Miller *in litt.* December 2023; A. Orme pers. comm. May 2024) and consequently a smaller maximum population estimate.

There are no long-term monitoring data available for this subspecies and no information on long-term population trends.

Ecology

Habitat

Hibbertia puberula subsp. *puberula* occurs in a wide range of habitats, but typically in low heath on sandy soil, or rarely in clay, with or without exposed bedrock (Toelken and Miller 2012). The subspecies also commonly occurs in dry sclerophyll woodland (Arcadis 2016; ALA 2023a; ANHSIR 2023a, 2023b; BioNet 2023b; RBGDT 2023b). Soil landscapes on which *H. puberula* subsp. *puberula* occurs include Hawkesbury, Lucas Heights, Faulconbridge, Oxford Falls, Berkshire Park, Blacktown, Glenorie, Sydney Town, Somersby, Lambert, Gymea, Richmond, Bundeena, Barren Grounds, Nowra, and Coolangatta (SALIS 2023). Underlying geologies include Hawkesbury Sandstone, Narrabeen Group Sandstone, Wianamatta Group Ashfield Shale, Bringelly Shale, Mittagong Formation, Quaternary alluvia of sand, silt and gravels, and Tertiary alluvia/colluvia of sand and clay (SALIS 2023).

Hibbertia puberula subsp. *puberula* occurs at elevations ranging from 0–850 m above sea level. Across its range, average annual rainfall ranges from 595 mm at Putty to 1,453 mm in Wahroonga, while mean temperatures range from 12.0–26.2°C in Moss Vale to 18.1–31.0°C in Penrith (BOM 2023).

Commonly co-occurring species include *Eucalyptus parramattensis*, *E. racemosa*, *E. punctata*, *Angophora bakeri*, *Corymbia gummifera*, *Gaudium trinervium*, *Banksia spinulosa*, *Hakea laevipes*, and *Calytrix tetragona* (ALA 2023a; ANHSIR 2023a, 2023b; BioNet 2023b; RBGDT 2023b; Miller *et al.* 2024). Co-occurring threatened species listed on the *Biodiversity Conservation Act 2016* include *Hibbertia fumana*, *Grevillea parviflora* subsp. *parviflora*, *Persoonia nutans*, *Leucopogon fletcheri* subsp. *fletcheri*, and *Darwinia biflora* (Arcadis 2016; M. Misdale pers. comm. 2022; ALA 2023a; BioNet 2023b; M. Saunders pers. obs. November 2023; RBGDT 2023b).

Hibbertia puberula subsp. *puberula* may occur in the following mapped Plant Community Types (PCTs): Budawang Damp Swamp Heath (PCT 3895), Morton Plateau Shrub Forest (PCT 3585), Shoalhaven Escarpment Peppermint-Silvertop Ash Forest (PCT 3689), South Coast Lowland Blackbutt Forest (PCT 3662), Woronora Plateau Heath-Mallee (PCT 3814), and Sydney Coastal Enriched Sandstone Forest (PCT 3592) (BioNet 2025). This list is not exhaustive, and it is likely that the subspecies occurs in other PCTs in NSW.

Hibbertia puberula subsp. *puberula* may occur in four threatened ecological communities (TECs) in the Sydney Basin Bioregion: Castlereagh Scribbly Gum Woodland in the Sydney Basin Bioregion, Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion, Castlereagh Swamp Woodland, and Shale Sandstone Transition Forest in the Sydney Basin Bioregion (Arcadis 2016; NSW DCCEEW 2024a).

Fire and disturbance ecology

Hibbertia puberula subsp. *puberula* is a facultative seeder (R. Miller pers. comm. December 2023) and resprouts after fire (G. Phillips pers. comm. December 2023).

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Reproductive and seed ecology

Hibbertia puberula subsp. *puberula* generally flowers from October to December but may flower as late as January (Toelken and Miller 2012). Seed set and release in the sister taxon *H. puberula* subsp. *glabrescens* has been documented to occur during the summer, typically within a month or so of flowering (Cuneo *et al.* 2018).

Hibbertia are insect-pollinated (entomophilous), with a range of insects including native bees (Apidae, Colletidae, and Halictidae), pollen-eating flies (Syrphidae), beetles (Coleoptera), and European honeybees (*Apis mellifera*), considered pollinators of *Hibbertia* flowers (Keighery 1975; Armstrong 1979; Tucker and Bernhardt 2000). However, there is debate over the primary vectors of *Hibbertia* pollen. Keighery (1975) found beetles to be the primary vectors of pollen of the zygomorphic *H. hypericoides*, while Tucker and Bernhardt (2000) considered native bees to be the most effective pollinators of zygomorphic *Hibbertia* species. As *H. puberula* subsp. *puberula* is zygomorphic, native bees and/or beetles are likely to be the primary pollinators.

Hibbertia puberula subsp. *puberula* seeds possess a fleshy aril (Toelken and Miller 2012), a structure that has been demonstrated to aid dispersal by ants (myrmecochory) in other *Hibbertia* species (Berg 1975). While ants have been documented transporting seeds of other species up to 77 m in sclerophyllous vegetation in the Southern Hemisphere, dispersal distances are typically <2 m (Gómez *et al.* 1998). As such, it is unlikely that seeds of *H. puberula* subsp. *puberula* are transported far from parent plants. *Hibbertia puberula* is known to have a persistent seedbank (Cuneo *et al.* 2018).

The specific germination cues of *Hibbertia puberula* subsp. *puberula* are unknown. *Hibbertia* seeds are known to be dormant at the time of release, although the type of dormancy varies from species to species, with both physiological dormancy (PD) and morphophysiological dormancy (MPD) recorded (Schatral *et al.* 1997; Allan *et al.* 2004; Hidayati *et al.* 2012). Seeds with PD are water-permeable but have a physiological inhibiting mechanism which prevents radicle emergence (Baskin and Baskin 2014) and require specific environmental triggers to promote germination (Penfield 2017). Seeds with MPD have a PD coupled with a rudimentary embryo which must grow to a critical size within the seed prior to germination (Baskin and Baskin 2014). Smoke or karrikinolide (KAR₁; a compound found in smoke) has been shown to aid germination in several *Hibbertia* species (Dalziell *et al.* 2004; Hidayati *et al.* 2012; Wulff *et al.* 2012). In a study of four sympatric *Hibbertia* species in Western Australia, Hidayati *et al.* (2012) found that seasonal changes in temperature and moisture were important factors influencing germination, while photo-regime affected one species, and smoke triggered germination in two species. Similarly, warm stratified seeds of *H. glaberrima* experienced higher germination rates than non-stratified seeds, with germination further increased by exposure to KAR₁ (Dalziell *et al.* 2004). Based on these studies, the environmental conditions required to enable *H. puberula* subsp. *puberula* to germinate probably include seasonal changes (e.g., changes in temperature and rainfall) and possibly the development of a rudimentary embryo. Given that the subspecies occurs in fire-prone environments, smoke may also be a trigger for germination.

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Lifespan and generation length

The primary juvenile period of *Hibbertia puberula* subsp. *puberula* is unknown. The species appears to be slow growing, with most seedlings of the sister taxon *H. puberula* subsp. *extensa* at one site recorded eight years post-fire inferred to be juveniles (Miller *et al.* 2024). This suggests that the species has a primary juvenile period of at least 7–8 years.

The lifespan of *Hibbertia puberula* subsp. *puberula* is not known. However, the closely related *H. sericea* is estimated to have a lifespan of 20–50 years (Falster *et al.* 2021), and this estimate is used for *H. puberula* subsp. *puberula* due to it belonging to the *H. sericea* group.

The generation length of *Hibbertia puberula* subsp. *puberula*, which is likely to rely on a combination of resprouting and seedling recruitment after disturbance, can be estimated using the age of first reproduction + z * length of reproductive period, where z is a number between 0 and 1 calculated on the relationship between survivorship and the relative fecundity of young versus old individuals in the population (IUCN 2024). Using a maximum lifespan of 20–50 years, a primary juvenile period of 7–8 years, and a value for z of 0.21 as calculated for other plant species with similar lifespans (Fung and Waples 2017), the generation length of *H. puberula* subsp. *puberula* is estimated at approximately 10.5–16 years.

Cultural significance

It is unknown whether *Hibbertia puberula* subsp. *puberula* has cultural significance to Aboriginal peoples. There is at least one species in the genus with recorded use. The Yaegl Aboriginal community in northern NSW used the leaves of *H. scandens* medicinally to treat sores and rashes (Packer *et al.* 2012).

This assessment is not intended to be comprehensive of the traditional ecological knowledge that exists for *Hibbertia puberula* subsp. *puberula*, or to speak for Aboriginal people. Aboriginal people have a long history of biocultural knowledge, which comes from observing and being on Country, and evolves as it is tested, validated, and passed through generations (Woodward *et al.* 2020). Aboriginal peoples have cared for Country for tens of thousands of years (Bowler *et al.* 2003; Clarkson *et al.* 2017). There is traditional ecological knowledge for all plants, animals and fungi connected within the kinship system (Woodward *et al.* 2020). Traditional ecological knowledge referenced in this assessment belongs to the relevant knowledge custodian and has been referenced in line with the principles of the NSW Indigenous Cultural and Intellectual Property protocol (ICIP) (Janke and Company 2023).

Threats

Hibbertia puberula subsp. *puberula* is threatened by the clearing, fragmentation, and degradation of habitat, particularly due to urban development, recreational vehicle use, and track maintenance, and adverse fire regimes, particularly high frequency fire and high severity fire.

Clearing, fragmentation, and degradation of habitat

The clearing, fragmentation, and degradation of habitat is considered a serious threat to *Hibbertia puberula* subsp. *puberula*. Approximately 69% (45) of the 65 *H. puberula*

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subsp. *puberula* subpopulations are fully or partially on non-reserved lands, defined here as freehold land, Crown land, and Council land. Many of these sites may be subject to clearing for residential, agricultural, or industrial purposes (OEH 2019). The high proportion of records found along and adjacent to roadsides, trail edges, and in easements increases the risk of habitat degradation and/or direct damage to individuals from road maintenance and slashing works, as well as illegal trailbikes, 4WDs and mountain bikes (OEH 2019). There is also the potential for widening of major roads to adversely affect several subpopulations (OEH 2019), particularly those in the south of the species range, where substantial numbers of individuals have been recorded along the sides of roads. Any development proximate to *H. puberula* subsp. *puberula* sites may result in altered hydrological conditions, soil pH and/or nutrient levels, facilitate weed invasion and the introduction of plant pathogens, and alter fire frequency.

A total of 260 records from the Moorebank, Voyager Point, Sandy Point, Holsworthy North, Holsworthy South, and Kellyville subpopulations – representing 736 individuals – appear to have been cleared for urban developments within the last eight years. Most of these occur in the Moorebank subpopulation, which has been adversely affected by the Moorebank Precinct East Project, with 255 records representing a minimum of 656 individuals destroyed for the development. The Heathcote Road upgrade has resulted in the loss of another 75 individuals (WSP 2016; SMEC 2019). Two records in the Voyager Point subpopulation appear to have been cleared on the edge of Heathcote Road, proximate to a housing development. One record from the Sandy Point subpopulation appears to have been cleared by a sand mine. The Kellyville subpopulation, represented by a single record, appears to have been replaced with an extensive housing development which includes most of the habitat within 1 km of the record, suggesting the complete loss of this subpopulation and associated AOO. The Holsworthy South subpopulation, represented by the single record, appears to have been replaced with an industrial development; however, due to spatial accuracy of the record stated at 5000 m, it is not possible to confirm the loss of this subpopulation.

Track widening and inappropriate recreational vehicle use threatens *Hibbertia puberula* subsp. *puberula* at several localities, including subpopulations around Mellong, in the southwest of Sydney, and in the Shoalhaven, with numerous records documented on roadside verges. Significant numbers of *H. puberula* subsp. *puberula* have been documented through surveys associated with the planned Princes Highway upgrades. All 41 known individuals from the Falls Creek West subpopulation occur within the project footprint of the Jervis Bay Road and Princes Highway intersection upgrade (DPE 2023; TfNSW 2024). The preferred strategic corridor between Falls Creek and Sussex Inlet (TfNSW 2020) is likely to lead to the loss of up to 106 individuals: six of the 34 known individuals from the Tomerong subpopulation and over 59 of the 544 known individuals from the Tullarwalla subpopulation occur within the preferred strategic corridor. Many of the records from the Mellong area occur proximate to 4WD tracks and are therefore at risk from recreational four-wheel driving (M. Saunders pers. obs. November 2023; Miller *et al.* 2024). Individuals recorded along the edges of major roads such as Heathcote Road in the southwest of Sydney or Braidwood Road in the Shoalhaven area, are at risk of roadside maintenance and upgrades, while individuals occurring within easements may be subjected to slashing and trittering, posing a risk of mortality and continued habitat degradation.

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'Clearing of native vegetation' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*. 'Land clearance' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Adverse fire regimes

Little is known about the fire ecology of *Hibbertia puberula* subsp. *puberula* but there is evidence that the species is vulnerable to adverse fire regimes, particularly high frequency and high severity fire. Fire has been documented to kill *H. puberula* subsp. *extensa* (Miller *et al.* 2024). More sampling is needed to understand potential variation in fire responses within and between these subspecies. Resprouters have been documented to be vulnerable to high severity fire, with higher fire severity leading to higher rates of mortality (e.g., Nicholson *et al.* 2017).

High frequency fire is also likely a threat to *Hibbertia puberula* subsp. *puberula*. As the species is thought to have a long primary juvenile period of up to 7–8 years (Miller *et al.* 2024), recurrent fires within shorter timeframes than this have the potential to greatly diminish or rapidly eliminate subpopulations. The ability of the species to resprout (G. Phillips pers. comm. December 2023) confers some resilience to recurrent short interval fires. However, repeated short interval fires can lead to depressed or failed resprouting in resprouting species (Enright *et al.* 2011; Karavani *et al.* 2018; Fairman *et al.* 2019).

Climate change projections indicate a future trend of increased fire weather and more frequent fires in southeast Australia (Dowdy *et al.* 2019; Jones *et al.* 2022). The Sydney, South East and Tablelands, Illawarra, Hunter, and Central Coast regions are projected to become hotter, have fewer cold nights under 2°C, have more hot days over 35°C, and have a longer fire season by 2079 (BOM and CSIRO 2022; AdaptNSW 2024). Regionally, it is projected with high confidence that climate change will result in a harsher fire-weather climate in the future (CSIRO 2024). It is plausible that these changes will lead to more frequent, intense, and severe fires, and changes in fire season, which will in turn adversely affect the *Hibbertia puberula* subsp. *puberula* population in the future.

'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*. 'Fire regimes that cause declines in biodiversity' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Severe fragmentation and number of locations

Hibbertia puberula subsp. *puberula* is considered to be severely fragmented as it is inferred that >50% of its population occurs in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance relative to dispersal kernel of the species, as per the IUCN (2024) definition.

This assessment has defined subpopulations by dispersal distance of pollinators; however, severe fragmentation considers the dispersal distance of the diaspore (*i.e.*, potential to recolonise), as per the IUCN (2024). Therefore, for the purposes of assessing whether *Hibbertia puberula* subsp. *puberula* is severely fragmented, habitat patches defined by probable seed dispersal distances are used. Seeds of the

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subspecies possess a fleshy aril (Toelken and Miller 2012), a structure that has been demonstrated to aid dispersal by ants in other *Hibbertia* species (Berg 1975), and ants typically disperse seeds of other species <2 m to 10s of metres in sclerophyllous vegetation in the Southern Hemisphere (Gómez *et al.* 1998. The IUCN (2024) states “distances several times greater than the (long-term) average dispersal distance of the taxon may be considered isolated”.

To meet the definition of *severely fragmented*, the IUCN (2024) states that “more than half of the individuals (or, more than half of the occupied habitat area) must be in small and isolated patches”, where “small” refers to a number below that required to support a viable population. While it is recognised that current records are likely to be a significant underestimate of the true population size of *Hibbertia puberula* subsp. *puberula* and recent surveys have shown the subspecies can be abundant in some areas (*e.g.*, Arcadis 2016), most records suggest that the subspecies generally occurs at low densities. This is consistent with observations that the subspecies is widespread but typically localised (Toelken and Miller 2012). The IUCN (2024) states that the condition of severely fragmented can be met by either more than half the individuals or *more than half of the occupied habitat area* being in small and isolated patches. Many habitat patches are small (most records with abundance data indicates <10 individuals, often 1–5) and isolated (by roads, expanses of urban or agricultural lands, fine-scale topographic features, or by distances in the order of hundreds of metres to kilometres). Furthermore, many of these habitat patches, such as those in the Liverpool – Appin and northern Sydney – Central Coast areas, are concentrated along edges of contiguous areas of bushland, which may limit their viability as a consequence of higher risk of human disturbance (*e.g.*, earthworks, dumping, off-road vehicles, and fires) and restricted options for dispersal to/from other suitable habitat. Given the subspecies’ limited dispersal ability, once an isolated habitat patch becomes locally extinct, the probability of recolonisation is low. Consequently, many of the small and isolated habitat patches are unlikely to viable in the long-term. This is evidenced by the loss of numerous habitat patches in the Moorebank, Voyager Point, Sandy Point, Holsworthy North, Holsworthy South, and Kellyville subpopulations. Furthermore, track widening and inappropriate recreational vehicle use threatens the persistence of numerous habitat patches around Mellong, in the southwest of Sydney, and in the Shoalhaven.

Hibbertia puberula subsp. *puberula* occurs at >10 threat-defined locations, as per the IUCN (2024) definition, due to the widespread and naturally disjunct distribution of the subspecies. The most serious plausible threat resulting in the lowest number of locations for the subspecies is adverse fire regimes, particularly high frequency fire and high severity fire; however, under this threat there are >10 threat defined locations, based on maximum historical fire extent. Urban areas not at risk of wildfire or prescribed burns are more threatened by the clearing, fragmentation, and degradation of habitat.

Assessment against IUCN Red List criteria

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

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Criterion A

Population size reduction

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%
<p>A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.</p> <p>A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p>A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) [(a) cannot be used for A3].</p> <p>A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p>		<p>based on any of the following:</p> <p>(a) direct observation [except A3]</p> <p>(b) an index of abundance appropriate to the taxon</p> <p>(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality</p> <p>(d) actual or potential levels of exploitation</p> <p>(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.</p>	

Outcome

Hibbertia puberula subsp. *puberula* is Data Deficient under Criterion A.

Population reductions

Of the estimated population size of 6,200 individuals (plausible range 2400–10,000), a minimum of 736 have been lost to urban development within the past 10.5–16 years (one generation length) and it is inferred that another 106 will be lost due to the Princes Highway upgrade up to 21–32 years into the future (two generation lengths). Based on this limited information, this could result in a 13.6% reduction (plausible range <8–35%) in the known population under this Criterion. However, there is insufficient information on trends in the other subpopulations to estimate declines across the taxon.

Conclusion

There is insufficient information to quantify population trends of *Hibbertia puberula* subsp. *puberula* under Criterion A.

Criterion B

Geographic range

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km ²	< 5,000 km ²	< 20,000 km ²
B2. Area of occupancy (AOO)	< 10 km ²	< 500 km ²	< 2,000 km ²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented OR Number of locations	= 1	≤ 5	≤ 10
(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			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Outcome

Hibbertia puberula subsp. *puberula* is Endangered under Criterion B2ab(ii,iii,iv,v).

EOO and AOO

The extent of occurrence (EOO) has been calculated at 12,941 km² and area of occupancy (AOO) have been calculated at 332–340 km².

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Number of threat-defined locations

Hibbertia puberula subsp. *puberula* occurs at >10 threat-defined locations, as per the IUCN definition (IUCN 2024).

Severely fragmented

The population of *Hibbertia puberula* subsp. *puberula* is inferred to be severely fragmented, as it is thought that >50% of its population occurs in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance relative to dispersal kernel of the species, as per the IUCN (2024) definition.

Continuing decline

The clearing, fragmentation, and degradation of habitat due to urban development is estimated and inferred to causing continuing decline in the number of mature individuals, and the area, extent, and quality of habitat, and inferred to be causing continuing decline in the area of occupancy and number of subpopulations. Urban development has been documented to have resulted in the loss of >700 individuals in the southwest and south of Sydney and another 100+ individual are in the preferred strategic corridor of the Princes Highway upgrade and inferred to be at risk of being lost in the near future.

It is inferred that up to two subpopulations have been lost due to urban development – the Holsworthy South and Kellyville subpopulations, However, given uncertainty around the location of the single record which represents the Holsworthy South subpopulation, only the Kellyville subpopulation is considered. The single record from 2015 which represents the Kellyville subpopulation has now been replaced with an extensive housing development, which includes most of the habitat within 1 km of the record. Consequently, continuing decline in AOO and the number of subpopulations is inferred.

Extreme fluctuations

There is no evidence to suggest *Hibbertia puberula* subsp. *puberula* undergoes extreme fluctuations.

Conclusion

Hibbertia puberula subsp. *puberula* is eligible to be listed as Endangered under Criterion B as it has a highly restricted geographic distribution (an AOO of 332–340 km²), is inferred to be severely fragmented, and is undergoing continuing decline in the area of occupancy, area, extent, and quality of habitat, number of subpopulations, and number of mature individuals.

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Criterion C Small population size and decline

C. Small population size and decline			
	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(ii) % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

Outcome

Hibbertia puberula subsp. *puberula* is Vulnerable under Criterion C1 and Criterion C2a(i).

Number of mature individuals

Hibbertia puberula subsp. *puberula* has an estimated population size of 6,200 (2,400 to >10,000) mature individuals, meeting the threshold for Vulnerable based on the best estimate. The plausible range (2400 to >10,000 individuals) also falls almost entirely within the range for Vulnerable status.

Continuing decline

Of the estimated population size of 6,200 individuals, a minimum of 736 have been lost to urban development within the past 10.5–16 years (one generation length), representing an 11.87% decline, meeting the requirements for Vulnerable under C1.

Mature individuals in each subpopulation

The Moorebank subpopulation of *Hibbertia puberula* subsp. *puberula* is estimated to support 1,065 individuals. However, given demographic information is not available for these records, it is considered likely that the number of *mature* individuals in this subpopulation is likely to be significantly less than 1,000. Furthermore, only two of the remaining 62–64 subpopulations support >100 individuals. As such, it is considered probable that no subpopulation supports >1000 mature individuals, meeting the threshold for Vulnerable.

% of mature individuals in a single subpopulation

The largest subpopulation of *Hibbertia puberula* subsp. *puberula* is estimated to support 44.9% of the known individuals.

Extreme fluctuations

There is no evidence to suggest *Hibbertia puberula* subsp. *puberula* undergoes extreme fluctuations.

Conclusion

Hibbertia puberula subsp. *puberula* is eligible to be listed as Vulnerable under Criterion C1 as it has an estimated population size of 6,200 individuals and there has been a minimum of 736 individuals have lost to urban development within the past 10.5–16

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years (one generation length), representing an 11.87% decline. Furthermore, the subspecies is eligible to be listed under Criterion C2a(i) as no subpopulation is thought to support >1,000 mature individuals.

Criterion D Very small or restricted population

D. Very small or restricted population			
	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	D1. < 1,000
D2. Only applies to the VU category Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	D2. typically: AOO < 20 km ² or number of locations ≤ 5

Outcome

Hibbertia puberula subsp. *puberula* is ineligible to be listed under Criterion D.

Number of mature individuals

The population size of *Hibbertia puberula* subsp. *puberula* is estimated to be 6,200 (2,400 to >10,000) mature individuals, exceeding the threshold required to meet this condition.

Risk of future extinction in a very short amount of time (D2)

Hibbertia puberula subsp. *puberula* has an area of occupancy of 332–340 km², occurs in >10 threat-defined locations, and has no plausible future threats that could rapidly drive the species to CR or EX in a short amount of time.

Criterion E Quantitative Analysis

E. Quantitative Analysis			
	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

Outcome

Hibbertia puberula subsp. *puberula* is considered Data Deficient under Criterion E.

Probability of extinction

No quantitative analysis has been undertaken to assess the extinction probability of this subspecies and there are currently insufficient data to undertake one.

Conservation and Management Actions

Hibbertia puberula is currently listed on the NSW *Biodiversity Conservation Act 2016* and a conservation project has been developed by the NSW Department of Climate Change, Energy, the Environment and Water. 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 puberula* sits within the Site-managed species management stream of the SoS program and the conservation project can be viewed here.

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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:

Hibbertia puberula subsp. *puberula* was found to be Endangered under Clause 4.3(b)(d)(e i,ii,iii,iv).

Clause 4.2 – Reduction in population size of species

(Equivalent to IUCN criterion A)

Assessment Outcome: Data Deficient

(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,	

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	(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,iv)

The geographic distribution of the species is:				
	(a)	for critically endangered species		very highly restricted, or
	(b)	for endangered species		highly restricted, or
	(c)	for vulnerable species		moderately restricted,
and at least 2 of the following 3 conditions apply:				
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,		
	(e)	there is a projected or continuing decline in any of the following:		
		(i)	an index of abundance appropriate to the taxon,	
		(ii)	the geographic distribution of the species,	
		(iii)	habitat area, extent or quality,	
		(iv)	the number of locations in which the species occurs or of populations of the species,	
	(f)	extreme fluctuations occur in any of the following:		
		(i)	an index of abundance appropriate to the taxon,	
		(ii)	the geographic distribution of the species,	
		(iii)	the number of locations in which the species occur or of populations of the species.	

Clause 4.4 - Low numbers of mature individuals of species and other conditions

(Equivalent to IUCN criterion C)

Assessment Outcome: Vulnerable under Clause 4.4(c)(d iii) and Clause 4.4(c)(e i,ii A(III))

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:		

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

**Clause 4.5 - Low total numbers of mature individuals of species
(Equivalent to IUCN criterion D)**

Assessment Outcome: Clause not met

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

**Clause 4.6 - Quantitative analysis of extinction probability
(Equivalent to IUCN criterion E)**

Assessment Outcome: Data Deficient

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

**Clause 4.7 - Very highly restricted geographic distribution of species—vulnerable species
(Equivalent to IUCN criterion D2)**

Assessment Outcome: Clause 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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