

NSW Threatened Species Scientific Committee

Conservation Assessment of *Phyloria pughi* Knowles, Mahony, Armstrong and Donnellan, 2004 (Limnodynastidae)

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***Phyloria pughi* Knowles, Mahony, Armstrong and Donnellan, 2004 (Limnodynastidae)**

Distribution: Endemic to NSW

Current EPBC Act Status: not listed

Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act and EPBC Act: Endangered

Conservation Advice: *Phyloria pughi* (Pugh's frog)

Summary of Conservation Assessment

Phyloria pughi was found to be eligible for listing as Endangered under Criterion B1ab (iii,iv,v) and B2ab (iii,iv,v).

The main reasons for this species being eligible are a very restricted geographical range and continuing decline as a result of ongoing threats, including the fragmentation and degradation of habitat, changed fire regimes, and climate change.

Description and Taxonomy

Phyloria pughi was described by Knowles *et al.* (2004) as "Body robust, pear-shaped. Head shorter than wide (HL/HW 0.64), head length approximately one quarter of SVL (HL/SVL 0.23). Snout blunt in profile. Nostrils more lateral than superior, closer to snout than to eye. Distance between eye and naris half that of internarial span (EN/IN 0.58). Canthus rostralis well defined and concave. Eye relatively large, its diameter greater than eye to naris distance (E/EN 1.5). Pupil shape horizontal when constricted. Tympanum small and indistinct. Tongue approximately rectangular. Vomerine teeth in two laterally aligned plates, separated in midline, behind level of choanae."

"No webbing on fingers or toes. Digits long, slender and cylindrical. Inner and outer palmar tubercles small but distinct. Fingers in decreasing order of length 3>2>4>1. Very weakly developed nuptial pad on first finger. Hindlimb short (TL/SVL 0.44). Toes in decreasing order of length 4>3>5>2>1. Inner metatarsal tubercle at base of first toe small but distinct. No outer metatarsal tubercle. Dorsum and abdomen smooth."

"Colour in life: Dorsum orange fading to yellow on flanks with small flecks of maroon. Crescent shaped black mark on mid-flank. Loreal region dark. A black band expanding posteriorly from snout through nostril along canthus rostralis, through eye along side of head to base of forearm. Blue sclera around eyes. Upper surfaces of limbs maroon, colour extending onto lower abdomen above vent. In preservative, abdomen pale, submandibular area and ventral surfaces of limbs, soles and palms, outer fingers and toes dark. Other fingers and toes with light banding."

Common Name: Pugh's sphagnum frog, Pugh's frog.

Distribution and Abundance

Phyloria pughii occurs across a restricted distribution at mid to high elevations (above 600 m asl) in far north-east New South Wales (NSW) from Gibraltar Range State Forest (SF), north-east of Glen Innes, through Gibraltar Range National Park (NP), Washpool NP and Forest Land SF to Girard SF, 70 km west of Casino (Knowles *et al.* 2004). Most of the distribution of *P. pughii* is within conservation reserves or areas managed for native timber industry.

The total estimated population size of *Phyloria pughii* is considered to be small but is not known with certainty. This species seems to naturally occur at low abundance, with a maximum of only six calling males recorded at any one site (M. Mahony pers. comm. September 2021; Knowles *et al.* 2004). Surveys conducted during the spring and summer seasons of 2017 and 2018 found the average number of males calling at a site was 2.5 with the maximum number of six (M. Mahony pers. comm. October 2021). Surveys conducted after the 2019–20 fires found only one to two calling males at sites (M. Mahony pers. comm. October 2021).

Note, in this assessment the word population is used to refer to the concept of 'subpopulation' in IUCN (2022), in keeping with the terminology used in the NSW BC Act, EPBC Act and other state/territory environmental legislation and general biological usage.

Ecology

The biology and ecology of the species is poorly understood, and further studies are required to provide information on population (size, structure, and dynamics), habitat requirements, and breeding biology.

Phyloria pughii is a habitat specialist typically found in high rainfall subtropical or temperate rainforest associated with boggy soaks or rocky creek beds in or near the headwaters of permanent streams (Knowles *et al.* 2004; Anstis 2017).

During breeding, pairs mate in concealed shallow burrows which the male excavates in mud, or under moss, rock or leaf litter (Knowles *et al.* 2004; Anstis 2017). Like other species of *Phyloria*, when not breeding this species is likely to be found foraging and sheltering amongst surface vegetation including in leaf litter, or under logs, rocks and root masses on the forest floor (Hollis 2003; Knowles *et al.* 2004).

Breeding occurs during spring and summer, usually from October to December (Knowles *et al.* 2004). Males call from the mating burrows in small congresses of up to six individuals (Knowles *et al.* 2004). The call is a very low pitched single repeated guttural 'oor' or 'ork' lasting ~120ms (Sanders 2021).

Although the reproductive biology of this species is not fully understood, it is likely similar to other *Phyloria* species and can be described in general (Hollis 2004; Knowles *et al.* 2004). Females lay a small clutch of eggs (40–42 for *P. pughii*; Knowles *et al.* 2004) in a jelly-like foam nest inside small, water-filled breeding chambers. Eggs are large and unpigmented and clutches at different stages of development may be found in the same nest site. The hatched embryos have two pairs of very small

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external gills (Anstis 2017). Tadpoles remain in the nest (with at least one parent) throughout their entire development, nourished solely by the egg yolk, until they emerge as metamorphs (Seymour *et al.* 1995; Knowles *et al.* 2004). Tadpoles have not been described but are likely to be similar to other *Phyloria* species in habit and development time (Anstis 2017).

Like other *Phyloria*, it is likely to have poor dispersal ability, moving no more than 1 km within its lifetime (M. Mahony pers. comm. October 2021; Anstis 2017). Radiotracking studies on the related Victorian species, *P. frosti*, indicate that both males and females likely migrate small distances (< 85 m for male; < 40 m for females) away from seepages after breeding, to occupy the upslope surrounding forest (Hollis 2003).

The diet of *Phyloria pughi* is not known, although other *Phyloria* species feed on a variety of insects including ants, wasps, spiders, flies and beetles (Lima *et al.* 2000).

The longevity of *Phyloria pughi* is unknown but based on the related species *P. frosti*, is estimated to be 9.5 years for males and 11.5 years for females (Hollis 2004). The minimum age of first reproduction is estimated to be two to three years (M. Mahony pers. comm. September 2021). Based on this information, an estimate of generation length is six years.

Threats

The main threats to *Phyloria pughi* are the ongoing fragmentation and degradation of its native habitat, changes in fire regimes, climate change and invasive fauna.

Loss, degradation and fragmentation of habitat:

In the past, large areas of the species' habitat were lost as a result of agricultural development, forest clearing and timber harvesting, however most of the remaining forest habitat where *Phyloria pughi* is distributed now falls within protected areas or state forest. Habitat degradation and fragmentation, nevertheless, continues due to ongoing timber harvesting, disturbances affecting hydrological processes, altered fire regimes, feral animals and weed invasion (Hines *et al.* 1999). The impacts of these disturbances on this species are unknown, but from the little knowledge of the ecology, including the species inability to move long distance, any increase in habitat loss and fragmentation is likely to be highly detrimental (Forero-Medina *et al.* 2011)

Changes in fire regimes:

In late 2019 and early 2020 wildfires burnt around 37% of the rainforests in New South Wales, including 54% of the NSW Gondwana Rainforests of Australia World Heritage Area (DPIE 2020). These forests are less fire-resilient and can be impacted significantly even at very low fire intensity (DAWE 2020a).

Rainforests usually persist within a mosaic of fire-prone *Eucalyptus* forest within areas where potential fuel usually has a higher moisture content (Nolan *et al.* 2020). The recent extreme drought in eastern Australia however, had dried the fuel to the point where wildfires spread through these less fire-resilient rainforests. Upland native eucalypt forest often surrounds rainforest and provides a physical buffer to solar radiation and windthrow. The loss of this protective habitat due to fire may result

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in further drying of the rainforest (Hines *et al.* 2020; M. Mahony pers. comm. October 2021).

Although there is little information available on the impact of fires on Australian frogs, *Philoria* species were assessed through expert elicitation to be one of the fire-affected taxa to have the most significant local population declines when exposed to severe fire (Legge *et al.* 2022). Adult and juvenile *P. pughii* may be directly killed as a result of forest fires, although as a fossorial species, they may not be as directly impacted by fire as much as other species of frogs that occur on the ground surface or in the canopy. Rowley *et al.* (2020) investigated short term persistence of amphibians after the recent fire events and noted that “small geographic ranges, especially rainforest-dependent species are of particular concern”. Indirect long-term impacts of fire on this species may include possible change from rainforest to sclerophyll forest, particularly where rainforest canopy trees are consumed or suffer high mortality rates during fire, sedimentation of headwater seepages, changes in soil structure and groundwater seepage, increased temperatures and evaporation in habitat where canopy loss is significant, a shortening of breeding season as calling activity of *Philoria* declines rapidly with increasing temperatures, and invasion by non-native species (including pigs and weeds) (Heard *et al.* 2021).

Fire overlap data estimates that 85% of *P. pughii* records were within the fire ground during the 2019–20 bushfires (DPIE 2020b) and initial estimates approximate that up to a maximum 91% of the species distribution was impacted to some extent by fire (with up to 18% severely burnt and 73% low-moderately burnt) (Legge *et al.* 2022). Large areas of the Timbarra Plateau and the two main national parks where the species is known to occur, Washpool NP and Gibraltar Range NP, were greatly affected by fire, some of which burnt into the subtropical and temperate forests (DAWE 2020a). The Ewingar Range area of the species distribution was not impacted by the fires.

Based on expert elicitation, it has been estimated that after 10 years the population size of *P. pughii* was likely to be 29% less abundant than it would have been had the fires not occurred (Legge *et al.* 2022). Surveys (using 200 m transects and song meters) of *P. pughii* across known sites conducted in the spring after the 2019–20 fires, indicated that the species was still present at all known areas, however abundance was lower than surveys conducted during the breeding season in 2017 and 2018, with only 1–2 males calling at most sites compared with 2–3 males calling previously (M. Mahony pers. comm. October 2021). The species was also not recorded in several severely burnt sites in Washpool NP and Timbarra Plateau, where they had previously been recorded (M. Mahony *in litt.* November 2021). Post-fire breeding, however, has been recorded in other sections of Washpool NP and Timbarra Plateau as well as the Gibraltar Range (M. Mahony pers. comm. September 2021). Around 85% of post-fire FrogID records of this species were from burnt sites of moderate or low intensity fires (Rowley *et al.* 2019; Rowley and Callahan 2020). This is consistent with post-fire survey outcomes for other *Philoria* species. Heard *et al.* (2021) undertook field surveys of *Philoria kundagungan*, *P. richmondensis* and *P. loveridgei* during the 2020–21 breeding season. The results suggest these species have some resilience to fire, with persistence detected for each of the studied species at burnt sites. Calling males of *P. kundagungan* and *P. richmondensis* were detected at sites that experienced moderate fire severity at lower numbers, indicating that

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these *Phyloria* species can initially survive fire events and will attempt to breed in burnt habitat when suitable conditions return.

The impacts of fire long-term for this species, however, are unknown, but given the frequency and intensity of fires is predicted to increase as a result of drying conditions associated with climate change, further impacts on habitat condition and availability are likely to have a detrimental effect on the species.

Climate Change:

Under current climate change projections, it is expected that minimum and maximum temperatures in the New England North West region will increase by 0.4–1.0°C and the region will experience more hot days (over 35°C) (DPIE 2020a). Similarly, rainfall is projected to decrease in winter and increase in autumn but the projections for summer span both wetting and drying scenarios and reflect the variability across the region (DPIE 2020a). The duration, frequency and intensity of droughts is expected to increase due to climate change, which subsequently is expected to increase the scale, frequency, and intensity of bushfires into the future (CSIRO and Bureau of Meteorology 2020). Climate projections for Gondwana Rainforests of Australian World Heritage Area indicate an increase in temperature and a decrease in humidity and cool season rainfall (Dowdy *et al.* 2015; Narsey *et al.* 2020). Climate models also suggest an increase in the base height of clouds in a warmer future, further intensifying drying trends (Narsey *et al.* 2020).

Frogs are particularly susceptible to climate change as they are sensitive to changes in environmental conditions and likely to be impacted by reduced rainfall, increased temperatures, and changes in fire regimes (Carey and Alexander 2003; Thomas *et al.* 2004; Urban *et al.* 2014; Hoffmann *et al.* 2021).

Climate change is considered a significant threat to the persistence of *P. pughii* and is predicted to further isolate subpopulations and reduce the available suitable habitat at lower elevations. Their reliance on saturated areas such as bogs and soaks, as well as their limited dispersal ability, small, isolated populations and slow growth rates make *Phyloria* species particularly sensitive to the impacts of climate change (Heard *et al.* 2020).

A severe decrease in rainfall and cloud stripping, resulting in the drying of headwater seepages, may lead to reduced reproductive output or mortality of eggs and tadpoles for this species. Further, the desiccation of microhabitats could lead to mortality of juveniles and adults, either through dehydration or a reduction in resource availability. Climate change is also likely to impact species indirectly through altered disturbance regimes, with the severity, frequency and seasonality of drought, flood and wildfire are all predicted to change under future climate scenarios.

A study by Heard *et al.* (2021) found that extent and severity of droughts are important determinants of the occurrence and abundance in other species of *Phyloria*. Detection and counts of calling males of *P. richmondensis* were significantly lower during a period of intense drought just prior to the fires in the summer of 2019–20, relative to surveys undertaken in the 2012–13 season. Significant winter and spring rainfall led to a recovery in occupancy and calling male abundance for *P. richmondensis* in 2020–21. Stream saturation extent, a measure of local drought stress, was a found

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to be a key predictor of occupancy (as measured by detection of calling males) for both *P. kundagungan* and *P. richmondensis* (Heard *et al.* 2021).

Disease – Chytridiomycosis caused by amphibian chytrid fungus:

Phyllorhina pughi may be susceptible to infection by the amphibian chytrid fungus, *Batrachochytrium dendrobatidis*. Chytrid is a water-borne pathogen virulent to adults of all frog species and causes the potentially fatal disease chytridiomycosis (Berger *et al.* 1999; Sheele *et al.* 2019). Chytridiomycosis is responsible for population declines in many frog species from eastern Australia, particularly upland stream-associated species from cool and temperate environments (Berger *et al.* 1999).

No individuals of *P. pughi* have been tested for chytrid and there are no reports of declines in this species as a result of this threat, however they occupy an environment which is considered to have a high chance of chytrid occurring (Murray and Skerratt 2012). Further, the amphibian chytrid fungus has been detected in *P. frosti* in Victoria (Hollis 2011) and the disease is implicated in population declines in this species (Skerratt *et al.* 2016).

Invasive fauna:

Feral pigs (*Sus scrofa*) are recognised as a threat to *Phyllorhina* species (Gillespie *et al.* 2020; M. Mahony pers. comm. September 2021). Pigs may prey directly on adults and eggs/larvae of this species and their wallowing and uprooting feeding behaviour can cause significant damage to the rainforest streams, disturbing nest sites and degrading habitat (M. Mahony pers. comm. September 2021). The impact of feral pigs on *Phyllorhina* species is exacerbated during periods of drought as they search out the limited areas of water. Feral pigs are currently known to occur in Washpool NP (NPWS 2005) and in Forest Land Flora Reserve (Forestry Corporation 2018).

Cattle grazing historically occurred in the state forests across the distribution of *P. pughi* for over 100 years until the 1980s (Forestry Corporation 2018). This practice is considered a threat to the species, mainly due to the trampling by cattle of nest sites, which was observed at least at one breeding site (Knowles *et al.* 2004). However, in recent years, feral cattle have been removed from most of its known sites. Cattle may still remain within some areas including Malara State Forest and Ewingar State Forest, but cattle grazing is no longer thought to pose a significant threat to the species (M. Mahony pers. comm. September 2021).

Little is known about predation of this species but feral predators, such as cats and foxes, may present a threat to adults and are recorded throughout its range (M. Mahony pers. comm. September 2021).

Other threats:

Post-fire weed invasion may be a threat for *Phyllorhina pughi* in burnt habitat. There has not been any recorded decline of this species due to the presence of weeds, however weeds are recognised as impacting other *Phyllorhina* species, and include Lantana (*Lantana camara*), Mist Flower (*Ageratina riparia*) and Crofton Weed (*Ageratina adenophora*) (Heard *et al.* 2021). These weeds impact the species by altering habitat structure and possibly subterranean hydrology and water availability, as well as potentially exacerbating future fire threat.

Photographers may pose a threat to the species as calling male *Phyloria* are typically rarely observed and it is necessary to disturb their habitat to see the frog, damaging breeding habitat and posing a risk for disease transmission.

Assessment against IUCN Red List criteria

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

Criterion A Population Size reduction

Assessment Outcome: Data Deficient

Justification: Generation length is unknown for this species, but based on related *Phyloria* species, is estimated to be six years. Therefore, the relevant timescale for this criterion is considered to be 18 years (three generations).

The population size of *Phyloria pughi* is unknown and information regarding population trends of the species is limited with all observations restricted to a small number of calling males. Although calling of *Phyloria* is often diurnal, non-calling individuals are difficult to detect due to their fossorial habits (Familiar-Lopez 2015).

Knowles *et al.* (2004) found that breeding congregations of this species were 'very small', with six being the largest number of calling males observed at any site. Surveys conducted during the spring and summer seasons of 2017 and 2018 found the average number of males calling at a site was 2.5 with the maximum number of six (M. Mahony pers. comm. October 2021). The recent 2019–20 bushfires are likely to have reduced the population of *P. pughi*, with initial analysis estimating that up to 91% of the distribution range overlapping with fire affected areas (Legge *et al.* 2022) and in some areas these fires burnt with high intensity (18% of distribution). Surveys of *P. pughi* across known sites conducted in the spring and summer seasons after the 2019–20 fires, indicated that the species was still present at most of these sites, however abundance was lower than previous surveys, with only 1–2 males calling at most sites and a decline of 30% has been estimated (M. Mahony pers. comm. October 2021). By combining the proportion of the species distribution estimated to have affected by fires, with expert elicitation on the population responses to various severities of fire, it is estimated that *P. pughi* experienced a population decline one-year post-fire of 35% (with an upper 80% confidence limit of 51%), as a result of the 2019–20 bushfires (Legge *et al.* 2022). This species was not predicted to recover by ten years post-fire, with an overall population size that was 39% lower than the pre-fire size (80% CL: -14 to -58), assuming no further extensive fire events.

However, the true impact of the 2019–20 bushfires on this species has yet to be determined and the actual amount of habitat burnt for this species is unknown. The bushfires will not have impacted all areas equally; some areas burnt at very high intensity whilst others burnt at lower intensity, potentially even leaving patches unburnt within a fire area. It is also not known how these frogs will respond post-fire. As a burrowing species it may not be as greatly directly impacted by fire as much as other species of frogs, though is likely to experience unfavourable post-fire conditions

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(including changes to habitat, loss of shelter sites and reduction of prey). Other species of *Phyloria* have also shown some initial resilience to fire (Heard *et al.* 2021).

To be listed as threatened under Criterion A, the species must have experienced a population reduction of $\geq 30\%$ (VU threshold) over three generations or 10 years (whichever is longer). Although the species may have undergone a reduction in population size, there are no quantitative data available on population size or dynamics and there are no data on population declines over the relevant time frame (18 years). Therefore, there are insufficient data to assess *P. pughii* against this criterion.

Criterion B Geographic range

Assessment Outcome: Endangered under Criterion B1ab (iii,iv,v) and B2ab (iii,iv,v)

Justification: *Phyloria pughii* is restricted to mid to high elevations (above 600 m asl) in the far north-east NSW from Gibraltar Range State Forest, north-east of Glen Innes, south to Girard State Forest, 70km west of Casino.

The extent of occurrence (EOO) for all known records for the species was estimated to be 1810 km², based on a minimum convex polygon enclosing all known mapped occurrences of the species, the method of assessment recommended by IUCN (2019). A species with an EOO of less than 5000 km² qualifies under the Endangered threshold.

The area of occupancy (AOO) for all records was estimated to be 212 km², based on 2 x 2 km grid cells, the scale recommended for assessing area of occupancy by IUCN (2019). A species with an AOO of less than 500 km² qualifies under the Endangered threshold.

Phyloria pughii meets the Endangered category for Criterion B1 and B2.

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

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

Assessment Outcome: Number of locations is ≤ 5 .

Justification: Although *P. pughii* is probably naturally range-restricted as a result of specific habitat needs, subpopulations have become isolated as a result of past clearing and habitat fragmentation, restricting the potential range of this species. In addition, this species has estimated low dispersal ability (less than 1 km; Anstis 2017). Ongoing threats such as changed fire regimes, climate change and invasive fauna are also likely to affect the future extent of the preferred habitat of this species. However there is no information available to determine if most of the habitat patches the species is known from are smaller than required to support a viable population, hence severe fragmentation is considered to be data deficient.

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There is considered to be 1 threat-based location with climate change being the main threat due to increased temperatures and change in precipitation patterns (impacting habitat availability and reproductive output).

It is also plausible that fire may become the main threat to the species, in which case there would be 4 threat-based locations, (Gibraltar, Washpool nth, Timbarra Plateau and Ewingar Range) (M. Mahony pers. comm. September 2021).

- 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: Continuing decline in iii,iv,v

Justification: Declines are projected to continue in area, extent and/or quality of habitat and inferred to continue in number of locations or subpopulations, and number of mature individuals, based on ongoing threats including, habitat loss and degradation, changes in fire regimes and climate change resulting in the contraction of suitable habitat for the species as well as the increasing incidence of droughts and bushfires.

- c) Extreme fluctuations.

Assessment Outcome: Data Deficient

Justification: There are no available data to suggest that extreme fluctuations occur in population size or geographic distribution of *Phyllorhina pughii*.

Criterion C Small population size and decline

Assessment Outcome: Data Deficient

Justification: The population size of *Phyllorhina pughii* is considered to be small but is not known with certainty (M. Mahony pers. comm. September 2021). Therefore, there is insufficient information to assess this species under Criterion C.

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) (CE); 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: Data Deficient

Justification: Following the 2019–20 bushfires experts estimated a decline of around 35% in abundance (Legge *et al.* 2022; M. Mahony pers. comm. October 2021). However, information on the response of frogs to fire is limited and there is no data available to estimate a decline in a suitable timeframe

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

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Assessment Outcome: Continuing decline

Justification: A continuing population decline is inferred based on the ongoing threats to the population including, habitat loss and degradation, changes in fire regimes and climate change resulting in the contraction of suitable habitat for the species as well as the increasing incidence of droughts and bushfires.

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: Data Deficient

Justification: There are no available census data to assess number of mature adults per subpopulation of the species, however the low number of calling males recorded at any one site indicates that number of mature individuals in each subpopulation is small, but is not known with certainty.

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

Assessment Outcome: Data Deficient

Justification: The percentage of mature adults per subpopulation is unknown. There are insufficient data to assess the species against this subcriterion.

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data Deficient

Justification: There are no available data to suggest that extreme fluctuations occur in population size or geographic distribution of this species.

Criterion D Very small or restricted population

Assessment Outcome: Not eligible

Justification: The population size of *Phyloria pughii* is considered to be small but is not known with certainty. The AOO is not considered to be very small ($<20 \text{ km}^2$).

To be listed under this criterion, a species must meet at least one of the two following conditions:

- D1. Population size estimated to number fewer than 50 (CR); 250 (E); 1,000 (V) mature individuals

Assessment Outcome: Data Deficient

Justification: The population size of *Phyloria pughii* is unknown. Therefore, there is insufficient information to assess this species under this subcriterion.

- D2. Restricted area of occupancy (typically $<20 \text{ km}^2$) 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.

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Assessment Outcome: Does not meet

Justification: AOO has been calculated to be 188 km² and so is not considered to be very restricted. Although there is estimated to be fewer than five threat-based locations (one location with climate change, resulting in increased temperature and decreased rainfall) as the main threat, there is no plausible future threat that could drive the taxon to Critically Endangered or extinct in a very short time. Therefore, the species does not meet the conditions for listing under this criterion.

Criterion E Quantitative Analysis

Assessment Outcome: Data deficient

Justification: Population viability analysis had not been undertaken and there are insufficient data to demonstrate if the species is eligible for listing under this criterion.

Conservation and Management Actions

This species is currently listed on the NSW Biodiversity Conservation Act 2016 and a conservation project has been developed by the NSW Department of Planning and Environment under the Saving our Species program. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *Phyloria pughii* sits within the Site-managed species management stream of the SoS program and the conservation project can be viewed here (<https://www.environment.nsw.gov.au/savingourspeciesapp/project.aspx?ProfileID=10971>).

Conservation and Management priorities

2019–2020 bushfire response

- As per guidance developed by Southwell (2020), conduct rapid on-ground surveys to establish extent of habitat and population loss as a result of the 2019-20 bushfires, and to provide a baseline for ongoing population monitoring. Note: population monitoring should only be conducted during the breeding season, particularly during peak calling activity, from late August to early December.
- Protect unburnt areas within or adjacent to recently burnt areas from further fire, in order to provide refuge sites, as well as protecting (from fire) unburnt areas that are not adjacent to burnt areas.
- Control introduced predators and pigs to support recovery of populations affected by fires, or populations near areas that have been affected by fire.
- Control introduced herbivores in burnt areas to support habitat recovery post fire.
- Establish the impact of fire retardants, used to fight bushfires, on frog populations.

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- Weed control and habitat restoration works may support the regeneration of forest habitat at some localised sites.

Habitat loss, disturbance and modifications

- Protect unburnt areas within or adjacent to recently burnt areas from further fire, in order to provide refuge sites, as well as protecting (from fire) unburnt areas that are not adjacent to burnt areas.
- Identify key breeding sites and implement a program ensuring habitat requirements are maintained.
- Investigate options for enhancing the resilience of the species' habitat to climate change.
- Investigate options for providing new habitat that would be suitable for the species under climate change scenarios.
- Reconnect isolated rainforest patches with corridors of wet forest, particularly along drainage lines in headwater streams.
- Protect the areas of occupancy of *Phyloria pughii* during the planning and implementation of controlled burns in the region.
- Maintain tracks, particularly boardwalks, and relocate recreational activities and roads away from sensitive habitat and breeding sites.

Invasive species (including threats from grazing, trampling, predation)

- In areas burnt by the 2019-20 bushfires, control of introduced predators may be required to support population recovery, and control of introduced herbivores will aid habitat recovery. Weed control and habitat restoration may be needed in localised areas to support habitat regeneration.
- Develop and implement longer-term strategies to control introduced and native predators by implementing eradication programs as necessary.
- Monitor and control damage to riparian areas by feral pigs. Control pig numbers and fence key sites, where feasible.
- Assess the impact of exotic weeds on habitat suitability for *Phyloria pughii*. If the impact is shown to be significant, develop a strategy for control or elimination of the invasive weeds.

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Impacts of domestic species

- Use fencing, or other measures where applicable, to reduce the access of domestic stock to stream banks.

Stakeholder Engagement

- Provide input into the various impact assessment and planning processes on measures to protect *Phyllorhina pughi* and its habitat. These include water resource plans, park management plans and environmental impact assessments.
- Interested nature conservation, Traditional Owner, land management and land holder groups could be engaged in conservation management activities, such as survey and monitoring, but should be made aware of the need to follow correct field practices and hygiene protocols to mitigate the risks of trampling and disease transmission. If necessary, use workshops to aid stakeholders in developing the skills and knowledge required to manage threats to this species while undertaking these activities.

Disease

- Collect and analyse samples from all monitoring programs for the species, to test for the presence of chytrid fungus, the susceptibility of *Phyllorhina pughi* to *Bd* and improve understanding of disease spread throughout the species' range.
- Minimise the spread of the amphibian chytrid fungus by implementing suitable hygiene protocols (Murray *et al.* 2011) to protect priority populations as described in the Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis (DOEE 2016).
- Provide disease identification and prevention protocols (methods of handling, diagnostic keys, etc.) to researchers and land managers for use in the field.

Survey and Monitoring priorities

- Conduct rapid on-ground surveys to establish extent of habitat and population loss as a result of the 2019–20 bushfires, and to provide a baseline for ongoing population monitoring. Note: population monitoring should only be conducted during breeding season, particularly during peak calling activity, from late August to early December.
- Regular monitoring should be undertaken for a small number of subpopulations from late August to early December when male frogs are known to call. Note: Frogs should not be disturbed at breeding sites under any circumstances.

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- Broadscale regular monitoring should be undertaken over the species' known range. Monitoring sites should span the altitudinal and latitudinal range and a range of other habitat characteristics. These data will be used to assess the species' status and assess further declines or re-establishment/recovery of subpopulations.
- Survey sites within the known range of the species where the environment is considered likely to be suitable for the species to identify whether subpopulations exist that are previously unknown.

Information and research priorities

- Understand the potential influence of climate change on the long-term survival prospects of the species, due to altered temperatures, rainfall patterns, bushfires, environmental stressors and diseases.
- Model microhabitat usage of this species beyond burrows, by gathering more detailed geo-climatic (e.g., soil moisture) and physiological data (e.g., operative temperatures and water loss).
- Measure the critical thermal limits and preferred temperatures of the species to ascertain its physiological limits, sensitivity and vulnerability. Include potential impacts of temperature on other life stages.
- Investigate options for linking, enhancing or establishing additional populations.
- Improve understanding of the extent and impact of infection by the amphibian chytrid fungus on *Phyllorhina pughii* to better inform how to apply existing or new management actions relevant to the recovery. This includes knowledge on:
 - the susceptibility of *Phyllorhina pughii* to the fungus;
 - the different strains of the fungus;
 - levels of virulence;
 - mechanisms for resistance to the disease;
 - treatment options;
 - husbandry methods;
 - the potential of other species to act as reservoirs or vectors for transmission of the fungus (DOEE 2016).
- Investigate population genetics to provide a baseline on effective population size, heterozygosity and structure among the various populations.
- Improve understanding of husbandry methods for the species.

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- Investigate options for reintroductions/translocations/augmentation from captive population if populations continue to become increasingly fragmented and isolated.

References

- Anstis M (2017) *Phyllorhiza pughii* In: 'Tadpoles and frogs of Australia, 2nd edition'. pp 512–513 (New Holland Publishers, Australia)
- Berger L, Speare R, Hyatt A (1999) Chytrid fungi and amphibian declines: overview, implications and future directions. In 'Declines and disappearances of Australian frogs'. (Ed. A. Campbell) pp. 23–33. (Environment Australia, Canberra).
- Carey C, Alexander MA (2003) Climate change and amphibian declines: is there a link? *Diversity and Distributions* **9**, 111–121.
- CSIRO and Bureau of Meteorology (2020) State of the Climate 2020. Commonwealth of Australia.
- DAWE (2020a) Gondwana Rainforests of Australia State of Conservation Update – April 2020. Department of Agriculture, Water and the Environment, Canberra. <https://www.environment.gov.au/system/files/resources/1bb2ae15-a6bf-4c18-8b53-adfa84c26cec/files/gondwana-rainforests-state-conservation-update-april-2020.pdf>
- DAWE (2020b) Consultation document on listing eligibility and conservation actions - *Phyllorhiza kundagungen* (Mountain Frog). Department of Agriculture, Water and the Environment.
- DOEE (2016). Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis, Commonwealth of Australia 2016. Available at: <http://www.environment.gov.au/biodiversity/threatened/publications/tap/infection-amphibians-chytrid-fungus-resulting-chytridiomycosis-2016> (accessed 18 October 2021).
- Dowdy AJ (2018) Climatological variability of fire weather in Australia. *Journal of Applied Meteorology and Climatology* **57**, 221–234
- DPIE (2020a) New England North West climate change snapshot. Office of Environment and Heritage, Sydney. Available at: <https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region/New-England-North-West-Climate-Change-Downloads> (accessed: 18 October 2021).
- DPIE (2020b) NSW Fire and Environment 2019-20 Summary. Biodiversity and Landscape Data and Analyses to Understand the Effects of the Fire Events. NSW Department of Planning, Industry and Environment, Sydney.

NSW Threatened Species Scientific Committee

- Familiar-López M (2015) 'Distribution, ecology, disease and physiology of a mountain-top endemic frog in the face of climate change: a study on *Phyllorhina loveridgei*.' Link. PhD thesis, Griffith University, Australia.
- Forero-Medina G, Joppa L, Pimm SL (2011) Constraints to species' elevational range shifts as climate changes *Conservation Biology* **25**, 163–171.
- Forestry Corporation (2018) Forest Land Flora Reserve – Site Specific Working Plan. NSW Government.
- Gillespie GR, Roberts JD, Hunter D, Hoskin CJ, Alford RA, Heard GW, Hines H, Lemckert F, Newell D, Scheele BC (2020) Status and priority conservation actions for Australian frog species. *Biological Conservation* **247**, 108543.
- Heard G, Bolitho L, Newell D, Hines H, McCall H, Smith J, Scheele B (2021) Post-fire impact assessment for priority frogs: northern *Phyllorhina*. NESP Threatened Species Recovery Hub Project 8.1.3 report, Brisbane.
- Hines HB, Brook M, Wilson J, MacDonald WJF, Hargreaves J (2020) The extent and severity of the MacKay highlands 2018 wildfires and the potential impact on natural values, particularly in the mesic forests of Eugella-credition area, *Proceedings of the Royal Society of Queensland* **125**, 139–157.
- Hines H, Mahony M, McDonald K (1999) An assessment of frog declines in wet subtropical Australia. In 'Declines and disappearances of Australian frogs'. (Ed. A. Campbell) pp. 44-63. (Environment Australia: Canberra).
- Hoffmann EP, Cavanough K L, Mitchell NJ (2021) Low desiccation and thermal tolerance constrains a terrestrial amphibian to a rare and disappearing microclimate niche. *Conservation Physiology* **9**, 1-15.
- Hollis G (2004) Ecology and conservation biology of the Baw Baw Frog *Phyllorhina frosti* (Anura: *Myobatrachidae*): distribution, abundance, autoecology and demography. PhD thesis, University of Melbourne, Australia.
- Hollis G (2011) National Recovery Plan for the Baw Baw Frog *Phyllorhina frosti*. Environment DoSa, Melbourne.
- IUCN Standards and Petitions Subcommittee (2019) Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Subcommittee.
<http://cmsdocs.s3.amazonaws.com/RedListGuidelines.pdf>
- Knowles R, Mahony M, Armstrong J, Donnellan S (2004) Systematics of sphagnum frogs of the Genus *Phyllorhina* (Anura: *Myobatrachidae*) in eastern Australia, with the description of two new species. *Records of the Australian Museum* **56**, 57–74.
- Legge S, Rumpff L, Woinarski JCZ, Whiterod NS, Ward M, Southwell DG, Scheele BC, Nimmo DG, Lintermans M, Geyle H, Garnett ST, Hayward-Brown B, Ensbey M, Ehmke G, Ahyong ST, Blackmore CJ, Bower DS, Brizuela-Torres D, Burbidge

NSW Threatened Species Scientific Committee

- AH, Burns PA, Butler G, Catullo R, Chapple DG, Dickman CR, Doyle K, Ferris J, Fisher D, Gallagher R, Gillespie GR, Greenlees MJ, Hohnen R, Hoskin CJ, Hunter D, Jolly C, Kennard M, King A, Kuchinke D, Law B, Lawler I, Lawler S, Loyn R, Lunney D, Lyon J, MacHunter J, Mahony M, Mahony S, McCormack RB, Melville J, Menkhorst P, Michael D, Mitchell N, Mulder E, Newell D, Pearce L, Raadik TA, Rowley J, Sitters H, Spencer R, Valavi R, West M, Wilkinson DP, Zukowski S (2022) The conservation impacts of ecological disturbance: time-bound estimates of population loss and recovery for fauna affected by the 2019-20 Australian megafires. *Global Ecology Biogeography*, **00**, 1-20.
- Lima AP, Magnusson WE, Williams DG (2000) Differences in diet among frogs and lizards coexisting in subtropical forests of Australia. *Journal of Herpetology* **34**, 40–46.
- Mann RM, Bidwell JR, Tyler MJ (2003) Toxicity of herbicide formulations to frogs and the implications for product registration: a case study from Western Australia. *Applied Herpetology* **1**, 13–22.
- Murray KA, Skerratt L, Marantelli G, Berger L, Hunter D, Mahony M, Hines H (2011) Hygiene protocols for the control of diseases in Australian frogs. Available at: <http://www.environment.gov.au/biodiversity/invasive-species/publications/hygiene-protocols-control-diseases-australian-frogs> (accessed: 18 October 2021)
- Narsey S, Laidlaw M, Colman R, Pearce K, Hopkins M, Dowdy A (2020) Impact of climate change on cloud forests in the Gondwana Rainforests of Australia World Heritage Area, Earth Systems and Climate Change Hub Report No. 20. NESP Earth Systems and Climate Change Hub, Australia.
- Nolan RH, Boer MM, Collins L, Resco de Dios V, Clarke H, Jenkins M, Kenny B, Bradstock RA (2020) Causes and consequences of eastern Australia's 2019-20 season of mega-fires. *Global Change Biology* **26**, 1039–1041.
- NPWS (2005) Gibraltar Range Group of Parks (incorporating Barool, Capoompeta, Gibraltar Range, Nymboida and Washpool National Parks and Nymboida and Washpool State Conservation Areas) Plan of Management. Department of Environment and Conservation (NSW).
- Rowley JJJ, Callaghan CT (2020) The FrogID dataset: expert-validated occurrence records of Australia's frogs collected by citizen scientists. *ZooKeys* **912**, 139-151.
- Rowley JJJ, Callaghan CT, Cornwell WK (2020) Widespread short-term persistence of frog species after the 2019–2020 bushfires in eastern Australia revealed by citizen science. *Conservation Science and Practice* **2020**, e287.
- Rowley JJJ, Callaghan CT, Cutajar T, Portway C, Potter K, Mahony S, Trembath DF, Flemons P, Woods A (2019) FrogID: Citizen scientists provide validated biodiversity data on frogs of Australia. *Herpetological Conservation and Biology* **14**, 155-170.

Sanders MG (2021) Photographic Field Guide to Australian Frogs. (CSIRO Publishing: Melbourne)

Seymour RS, Mahony MJ, & Knowles R (1995). Respiration of embryos and larvae of the terrestrially breeding frog *Kyarranus loveridgei*. *Herpetologica* **51**, 369-376.

Scheele BC, Pasmans F, Skerratt LF, Berger L, Martel A, Beukema A, Acevedo, AA, Burriwes PA, Carvalho T, Catenazzi A, DelaRiva I, Fisher MC, Fleechas SV, Foster CN, Frias-Alvarez P, Garner TWJ, Gratwicke B, Guayasamin JM, Hirschfeld M, Kolby JE, Kosch TA, LaMarca E, Lindenmayer DB, Lips KR, Longo AV, Maneyro R, McDonald CA, Mendelson J, Palacios-Rodriguez P, Parra-Olea G, Richards-Zawacki CL, Rödel MO, Rovito SM, Soto-Azat C, Toledo LF, Voyles J, Weldon C, Whitfield SM, Wilkinson M, Zamudio KR, Canessa, S (2019) Amphibian fungal panzootic causes catastrophic and ongoing loss of biodiversity. *Science* **363**, 1459–1463.

Skerratt LF, Berger L, Clemann N, Hunter DA, Marantelli G, Newell DA, Philips A, McFadden M, Hines HB, Scheele BC, Brannelly LA, Speare R, Versteegen S, Cashins SD, West M (2016) Priorities for management of chytridiomycosis in Australia: saving frogs from extinction. *Wildlife Research* **43**, 105–120.

Southwell D, Hao A, Smart A, Valavi R, Wilkinson D, Wintle B (2020) Design considerations for post natural disaster (fire) on-ground assessment of status of species, ecological communities, habitats and threats. Threatened Species Recovery Hub. Available at: <https://www.nespthreatenedspecies.edu.au/media/zu1lcusd/8-1-1-design-considerations-for-post-natural-disaster-fire-on-ground-assessment-of-status-of-species-ecological-communities-habitats-threats.pdf> (accessed: 18 October 2021)

Thomas C, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, Erasmus BFN, De Siqueira MF, Grainger A, Hannah L, Hughes L, Huntley B, Van Jaarsveld AS, Midgley GF, Miles L, Ortega-Huerta MA, Peterson AT, Phillips OL, Williams SE (2004) Extinction risk from climate change. *Nature* **427**, 145–148.

Urban MC, Richardson JL, Freidenfelds NA (2014) Plasticity and genetic adaptation mediate amphibian and reptile responses to climate change. *Evolutionary Applications* **7**, 88–103.

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Appendix 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria

The Clauses used for assessment are listed below for reference.

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,	
	(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 ii, iii, iv).

[Equivalent to IUCN Criterion B Endangered via B1ab (iii, iv,v) and B2ab (iii, iv,v)]

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:	

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	(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: Data Deficient

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,

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		(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: Data Deficient**

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 4.7 was 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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