Conservation Assessment of sphagnum frog *Philoria sphagnicola* (Moore, 1958) (Limnodynastidae)

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NSW Threatened Species Scientific Committee

***Philoria sphagnicola* (Moore, 1958) (Limnodynastidae)**
Distribution: Endemic to NSW
Current EPBC Act Status: not listed
Current NSW BC Act Status: Vulnerable as *Philoria sphagnicolus*

Proposed listing on NSW BC Act and EPBC Act: Vulnerable

Conservation Advice: *Philoria sphagnicola (sphagnum frog)*

Summary of Conservation Assessment

Philoria sphagnicola was found to be eligible for listing as Vulnerable under Criterion B1ab (ii,iii,iv,v) and B2ab (ii,iii,iv,v).

The main reasons for this species being eligible are a 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

Philoria sphagnicola is described by Knowles *et al.* (2004) as "A small, robust, ground dwelling frog. Adult males (n = 91) measure 24 to 35 mm and females (n = 17) 29 to 37 mm SVL. Head shorter than wide (HL/HW mean 0.68, range 0.57–0.85). Head length approximately one-quarter snout to vent length (HL/SVL mean 0.25, range 0.20–0.30). Hind limbs short (TL/SVL mean 0.46, range 0.38–0.51). Ratio of eye to naris distance to internarial span variable (EN/IN mean 0.63, range 0.44–1.04). Dorsal colour varies from cream through various shades of yellow to orange, red or black usually with irregular spots or patches. Black patches on lower dorsum at an oblique angle over ilium, less frequently extending to and joining at midline in an arrow shape with apex directed anteriorly or, in about one third of specimens, lower dorsum is unmarked. Some dark specimens with a broad cream vertebral band. Dorsal skin usually smooth, occasionally with a few tubercules or short raised ridges along mid-dorsolateral area aligned along long axis of body. Ventral surfaces vary from white to orange often with darker brown to black mottling on abdomen, throat and under-surfaces of limbs. Palms vary from completely dark to completely pale but subarticular and palmar tubercules always pale. Soles completely dark but first and second fingers always pale. A brown or black stripe extending from nostril through eye to base of arm always present but variably developed. Flank with or usually without a black band. A horizontal black band extending laterally from over cloaca to ventral surface of thigh. Vomerine teeth posterior to and extending to inner edge of choanae. Fingers in decreasing order of length 3>2>4>1. Toes in decreasing order of length 4>3>5>2>1. Well-developed dark nuptial pad on first finger of males and a spatulae on each of first and second fingers of females."

There is genetic structuring between populations north and south of the Hastings River, in the mid-north coastal ranges (Knowles *et al*. 2004). Further research is

needed to clarify the taxonomic implications of this divergence (M. Mahony pers comm. November 2021).

Synonym: *Philoria sphagnicolus* Moore, 1958

Common Name: sphagnum frog

Distribution and Abundance

Philoria sphagnicola has a scattered distribution along the eastern escarpment of the Great Dividing Range in north-east New South Wales (NSW), from the Comboyne Plateau and Hastings River catchment in the south, northwards to Chaelundi State Forest. Within this distribution there are several conservation reserves including Werrikimbe, Willi Willi, New England, Dorrigo and Bellinger River National Parks (NP), Mount Hyland and Mount Seaview Nature Reserves (NR), a number of timber reserves (including Mt Banda Banda and Rimau Road) and several state forests (Brooklana, Marengo, Mistake, Mt Boss, Never Never, Nulla Five Day, Oakes, Ramornie, Styx River, and Wild Cattle Creek).

The total population size of *P. sphagnicola* is unknown. This species seems to naturally occur at low abundance, with a maximum of up to 20 calling males recorded at any one site (Knowles *et al.* 2004). In surveys conducted during the spring and summer calling seasons of 2017 and 2018, the average number of males calling was three to four, with a maximum of seven (M. Mahony pers. comm. October 2021). Recent surveys conducted after the 2019–20 fires found only one to two calling males at known breeding sites and an absence of calling males at many lower altitude 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

Philoria sphagnicola is a habitat specialist typically found in wet sclerophyll forest or subtropical rainforest habitats at elevations above 600 asl, but can also occur at lower elevation (to about 250 m) in wet coastal foothills (de Bavay 1993; Sanders 2021). This species is usually found associated with sphagnum moss beds or seepages on steep slopes, 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). Some populations of *P. sphagnicola* also utilize cracks in rock faces for their nests (Moore, 1958). Like other *Philoria*, when not breeding this species is likely to be found foraging or sheltering amongst surface vegetation including leaf litter, or under logs, rocks and root masses on the forest floor (Hollis 2003; Knowles *et al.* 2004).

Breeding occurs in spring and summer, usually in October to December in the northern localities and October to January in the mid-north coastal ranges (Anstis 2017). Males call from the mating chambers often just before dawn or dusk, or during

overcast conditions (Sanders 2021). The call is a very low pitched ‘b-o-o-rk’ lasting about 0.4 of a second and repeated steadily about 3–5 seconds apart (Anstis 2017).

Females lay a small clutch of eggs (mean 58.3, range 30–91) in a jelly-like foam nest inside these small water-filled breeding chambers (de Bavay 1993; Anstis 2017). Eggs are large (3.35 +/- 0.21 mm), creamy-white and unpigmented. The hatched embryos have two pairs of very small external gills. Clutches at different stages of development may be found in the same nest site (Anstis 2017). Tadpoles can reach a total length of up to 2.5 cm, and are mostly transparent white, only developing grey or brown colour in later growth stages. Larvae remain in the nest (with at least one parent) throughout their entire development (nourished solely by the egg yolk) until they emerge as metamorphs one and a half to three months later, depending on water temperature (Knowles *et al.* 2004; Anstis 2017).

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

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

The longevity of *Philoria sphagnicola* 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 *Philoria sphagnicola* are the ongoing fragmentation and degradation of its native habitat, changes in fire regimes and climate change and invasive fauna.

Loss, degradation and fragmentation of habitat:

In the past, large areas of the species’ habitat of higher altitude forest were lost as a result of agricultural development, forest clearing and timber harvesting and this is likely to have decreased the species abundance (Knowles *et al.* 2004).

Although much of the remaining forest habitat where *Philoria sphagnicola* is distributed now falls within protected areas, timber harvesting and native hardwood plantations continue in some of the state forests where the species occurs (including Riamukka, Enfield, Comboyne, and Bulga State Forests). Habitat degradation and fragmentation also continue due to disturbances affecting hydrological processes, altered fire regimes, feral animals and weed invasion (Hines *et al*. 1999). The impact of these disturbances on this species is unknown, but from the little knowledge of its ecology, including the species inability to move long distances, 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 states Gondwana Rainforests of Australia World Heritage Area (DPIE 2020c). 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 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. sphagnicola* may be directly killed as a result of forest fires, although as a fossorial species, it may not be as greatly directly impacted by fire as other species of frogs. 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).

Mapping of the extent and severity of the 2019–20 fires estimates that up to 64% of the species distribution was impacted to some extent by fire (with 21% very severely burnt) (Legge *et al.* 2022). High intensity fires occurred across Werrikimbe NP, Willi Willi NP, Dunggir NP, Ellis SF and Mount Hyland NR all of which have records of this species.

Other species of *Philoria* have shown some initial resilience to fire in the short term (Heard *et al*. 2021), however surveys of *P. sphagnicola* (using 200m transects and song meters) across known and historic sites conducted in the spring and summer seasons after the 2019–20 fires, did not detect the species at almost half of the known sites, especially those at lower altitudes. Abundance was also low in other areas, with only one to two males calling at most sites (up to a maximum of six), as compared with an average of three to four males calling (maximum of seven) in surveys conducted during breeding seasons in 2017 and 2018 (M. Mahony pers. comm. October 2021). Around 75% of post-fire FrogID records of this species were from unburnt sites, the remainder of the records being sites that had experienced low or moderate intensity fires (Rowley *et al*. 2019; Rowley and Callahan 2020).

These survey results infer a possible population decline including potentially a loss of populations, but it is unknown if this is all a direct result of the fires or if it is also due to pre fire drought. While the majority of the known occupied (historic) sites where *P. sphagnicola* were not recorded had been burnt, there were several unburnt sites, where no frogs were recorded, including several where conditions seemed suitable for breeding (M. Mahony pers. comm. October 2021).

The impacts of fire long-term for this species are unknown, but given that the frequency and intensity of fires is predicted to increase as a result of 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 and North Coast regions will increase in the near future by 0.4–1.0°C and the region will experience more hot days (over 35°C) (DPIE 2020a; b). Similarly, rainfall is projected to decrease in winter and increase in autumn and spring but the projections for summer span both wetting and drying scenarios and reflect the variability across the region (DPIE 2020a; b). 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 (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). 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. sphagnicola* 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 *Philoria* species 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 effects on hydration 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 (CSIRO and Bureau of Meteorology 2020).

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 *Philoria*. 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 found to be a key predictor of occupancy (as measured by detection of calling males) for both *P. kundagungan* and *P. richmondensis*.

Disease – Chytridiomycosis caused by amphibian chytrid fungus:
Philoria sphagnicola may be susceptible to infection by the amphibian chytrid fungus, *Batrachochytrium dendrobatidis*. Chytrid fungus is a water-borne pathogen virulent to adults of all frog species and causes the 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. sphagnicola* 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 & Skerratt 2012) and deaths due to chytrid have been reported for the sympatric *Litoria daviesae* (M. Mahony pers. comm. September 2021). Chytrid has also been recorded in congeneric species, including *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 *Philoria* species (Gillespie *et al.* 2020; M. Mahony pers. comm. September 2021). Pigs may prey directly on both adults and nestlings 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 these species is exacerbated during periods of drought as they search out the limited areas of water. Feral pigs are known to cause problems in *P. sphagnicola* habitats in Riamukka SF.

Cattle grazing historically occurred in the state forests across the distribution of *P. sphagnicola* and this is considered a threat to the species due to trampling of nest sites (Knowles *et al.* 2004). In recent years, feral cattle have been removed from most of the known *P. sphagnicola* sites and this is no longer thought to pose a significant threat to the species. (M. Mahony pers. comm. September 2021).

Little is known about predation on 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 *Philoria sphagnicola* 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 *Philora* species, including 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 the subterranean hydrology and water availability, as well as potentially exacerbating future fire threat.

Photographers may pose a threat to the species as calling male *Philoria* are typically detected 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 *Philoria sphagnicola* 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 *Philoria* 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 *Philoria sphagnicola* is unknown and information regarding population trends of the species is limited, with all observations restricted to a small number of calling males. Although *Philoria* are often diurnal, non-calling individuals are difficult to detect due to their fossorial habits (Familiar-Lopez 2015).

Knowles *et al.* (2004) found that breeding congresses of this species were generally 'relatively small' though some (seven) locations had ten or more calling males in a breeding congress, and two of these had 20 or more. Surveys conducted during the spring and summer seasons of 2017 and 2018 found the average number of males calling was three to four, with a maximum of seven (M. Mahony pers. comm. October 2021). The recent 2019–20 bushfires are likely to have reduced the population of *P. sphagnicola* and may have accelerated decline, with 64% of the distribution range overlapping with fire affected areas (Legge *et al.* 2022) and in some areas these fires burnt with high intensity (~20% of distribution). Surveys of *P. sphagnicola* across known sites conducted in the spring and summer seasons after the 2019–20 fires indicated that the species was absent at almost half of the known sites. This was especially at lower altitudes and abundance was low in other areas with only one to two males calling at most sites (M. Mahony pers. comm. October 2021). It is unknown if these declines and potential losses of populations are solely the result of fire.

To be listed as threatened under Criterion A, the species must have experienced a population reduction of ≥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 the population size or dynamics of this animal and there are no data on population declines over any relevant time frames (10 years or 3 generations). Therefore, there are insufficient data to assess *P. sphagnicola* against this criterion.

Criterion B *Geographic range*

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

Justification: *Philoria sphagnicola* is restricted to a series of isolated populations along the eastern escarpment of the Great Dividing Range in north-east New South Wales (NSW), from the Comboyne Plateau and Hastings River catchment in the south, northwards to Chaelundi State Forest.

The extent of occurrence (EOO) for all known records for the species was estimated to be 13 866 km^2, 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 20 000 km^2 qualifies under the Vulnerable threshold.

The area of occupancy (AOO) for all records was estimated to be 820 km^2, 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 2 000 km^2 qualifies under the Vulnerable threshold.

Philoria sphagnicola meets the Vulnerable 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. sphagnicola* is probably naturally restricted as a result of specific habitat needs, populations have become isolated as a result of past clearing and habitat fragmentation, restricting the potential range of this species. In addition, this species has very 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.

   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 (Dorrigo plateau; New England NP; Hastings Range; and Lansdowne Plateau, (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 ii,iii,iv,v

Justification: There is a continuing decline in 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, 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 and intensity 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 *Philoria sphagnicola.*

Criterion C *Small population size and decline*

Assessment Outcome: Data Deficient
Justification: The population size of *Philoria sphagnicola* 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 2019–2020 bushfires experts estimated a decline of around 20-40% in abundance (M. Mahony pers. comm. October 2021; Legge *et al.* 2022). However, information on the response of frogs to fire is limited and there are 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.

Assessment Outcome: Continuing decline

Justification: A continuing decline is inferred from ongoing threats including, habitat loss and degradation, changes in fire regimes and climate change resulting in the contraction of available suitable habitat for the species as well as the increasing incidence and intensity 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 the 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 *Philoria sphagnicola* is considered to be small but is not known with certainty. The AOO is not considered to be very small (<20 km^2).
To be listed under D, 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 *Philoria sphagnicola* is unknown. Therefore, there is insufficient information to assess this species under this subcriterion.

D2. Restricted area of occupancy (typically <20 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.

Assessment Outcome: Does not meet

Justification: AOO has been calculated to be 820 km^2 and so is not considered to be very restricted. Although there is estimated to be less than five threat-based locations (one location with climate change as the main threat (due to increased temperatures and change in precipitation patterns impacting habitat availability and reproductive output), 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. *Philoria sphagnicola* sits within the Landscape species management stream of the SoS program and the conservation project can be viewed here (https://www.environment.nsw.gov.au/savingourspeciesapp/Project.aspx?results=c&ProfileID=10620).

Conservation and Management priorities

2019–20 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 unburnt areas that are not adjacent to burnt areas from fire.
- 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.
- Weed control and habitat restoration works may support the regeneration of forest habitat at some localised sites. Note that herbicide formulations can be toxic to frogs and tadpoles, particularly if they contain glyphosate and surfactants (Mann *et al.* 2003).

Habitat loss, disturbance and modifications

- Protect unburnt areas within or adjacent to recently burnt areas from further fire to provide refuge sites, as well as protecting unburnt areas that are not adjacent to burnt areas from fire.
- Identify key breeding sites and implement a program ensuring suitable habitat is maintained.
- Investigate options for enhancing the resilience of the species' current 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 stream headwaters.
- Protect the areas of occupancy of sphagnum frog during the planning and implementation of controlled burns in the region.
- Maintain tracks, particularly board-walks, 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; control of introduced herbivores will aid habitat recovery. Weed control and habitat restoration may be needed in localised areas to support habitat regeneration. Note that herbicide formulations can be toxic to frogs and tadpoles, particularly if they contain glyphosate and surfactants (Mann *et al.* 2003).
- 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 sphagnum frog. If the impact is shown to be significant, develop a strategy for control or elimination of the invasive weeds. Note that herbicide formulations can be toxic to frogs and tadpoles, particularly if they contain glyphosate and surfactants (Mann *et al*. 2003).

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 sphagnum frog and its habitat. These include water resource plans, park management plans and environmental impact assessments.
- Interested nature conservation, 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 the sphagnum frog to chytrid fungus, 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.
- Broadscale regular monitoring should be undertaken over the species' known range. 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 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 sphagnum frog to better inform how to apply existing or new management actions relevant to the recovery. This includes knowledge of:
    - the susceptibility of sphagnum frog 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 for effective population size, heterozygosity and structure among the various populations.
- Improve understanding of husbandry methods for the species.
- Investigate options for reintroductions/translocations/augmentation from captive population if populations continue to become increasingly isolated.

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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: Vulnerable under Clause 4.3 (c) (d) (e ii, iii, iv).
[Equivalent to IUCN Criterion B Vulnerable via B1ab (ii, iii, iv,v) and B2ab (ii, 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:	

		(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,

			(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 is not meet

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.