

# NSW Threatened Species Scientific Committee

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## Conservation Assessment of Davies' Tree Frog *Litoria daviesae* Mahony, Knowles, Foster & Donnellan 2001 (Hylidae)

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### ***Litoria daviesae* Mahony, Knowles, Foster & Donnellan 2001 (Hylidae)**

Distribution: Endemic to NSW

Current EPBC Act Status: not listed

Current NSW BC Act Status: Vulnerable

Proposed listing on NSW BC Act and EPBC Act: Vulnerable

### **Conservation Advice: *Litoria daviesae***

#### **Summary of Conservation Assessment**

*Litoria daviesae* 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, severe fragmentation, and continuing decline as a result of ongoing threats, including, the fragmentation and degradation of habitat, amphibian chytrid fungus, adverse fire regimes, invasive fauna and climate change.

#### **Description and Taxonomy**

*Litoria daviesae*, a member of the *Litoria citropa* species group, was described by Mahony *et al.* (2001) as: "Head approximately as long as broad (HL/HW 1.04), and approximately one third snout to vent length (HL/SV 0.38). Snout prominent, blunt when viewed from above and in profile. Nostrils more lateral than superior, closer to snout than to eye. Distance between eye and naris equal to internarial span (EN/IN 1.08). Canthus rostralis well defined and straight. Eye relatively large, its diameter greater than eye to naris distance. Pupil horizontal when constricted. Tympanum small, indistinct, and oval with long axis tilted towards eye. Tympanum length approximately half eye diameter (T/E 0.45). Well-developed supratympanic fold, glandular in appearance, that partially obscures tympanic region. Vomerine teeth long curved plates directed posteriorly from the front margin of the choanae. Tongue approximately rectangular."

"Fingers long, slender, unwebbed. Subarticular and palmar tubercles prominent. Terminal discs expanded, extending beyond lateral extremities of penultimate phalanx. Fingers in order of length 3>4>2>1. Hindlimb length moderate (TL/ SV 0.58). Toes in order of length 4>5=3>2>1. Webbing reaches base of second most distal phalanx on toe 4 and penultimate phalanx on other toes. Subarticular tubercles prominent. Small oval inner metatarsal tubercle present. Terminal toe discs slightly expanded, just extending beyond lateral extremities of penultimate phalanx."

"Dorsum lightly shagreened. Abdomen, undersurface of thighs, submandibular area and lateral aspect of body mildly granular. There is a broad and prominent gland covered by smooth skin around the margin of the submandibular area. Pectoral fold

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and vocal sac are absent. Dimensions of holotype (mm) SV 44.3, HL 15.4, HW 15.1, EN 3.7, IN 2.8, E 4.5, T 1.9.”

“Colour in preservative. Base colour of dorsum uniform dark grey, with some small black speckles from base of head to vent. Upper surfaces of limbs same base colour as dorsum and lightly speckled with black. Dark grey base colour of dorsum becomes patchy on lateral aspect of body as base colour is replaced by lighter grey tone, eventually being replaced by flesh colour on venter. Upper lip margin bordered by fine cream line extending from snout to end of jaw where it is expanded. Anterior surface of thigh flesh coloured, without patterning. Venter and undersurfaces of hands and feet cream, throat lightly suffused with light gray wash, edge of mandible dark gray.”

This species can be distinguished from all other members of the *L. citropa* species group, except *L. citropa* and *L. subglandulosa*, by the presence of the prominent supratympanic fold and submandibular gland. It can be distinguished from *L. citropa* by the absence of vocal sac (present in *L. citropa*), hidden tympanum (distinct in *L. citropa*), dorsum either with or without sparsely distributed, small, raised “warts” in *L. daviesae* versus frequent small, raised “warts” with black pigmentation to distal end in *L. citropa*. *L. daviesae* was previously recognised as part of *L. subglandulosa*, from which it can be distinguished by its lightly shagreened skin, its uniform golden brown to mottled brown and green colouration, and greater body length (up to 63 mm, compared to 50 mm for *L. subglandulosa*) (Mahony *et al.* 2001).

Common Name: Davies’ Tree Frog

## Distribution and Abundance

*Litoria daviesae* is endemic to central-eastern to lower-northeastern New South Wales (NSW), from Barrington Tops in the south, 150 km north to Carrai Plateau. Its habitat is highly fragmented, and it is restricted to a series of small populations along the eastern escarpment of the Great Divide and adjacent tablelands above 400 m elevation (Mahony *et al.* 2001). Most of the distribution of *L. daviesae* is within conservation reserves (including Barrington Tops National Park (NP) and Werrikimbe NP) or areas managed for native timber industry.

The total estimated population size of *Litoria daviesae* is unknown and information regarding population trends of the species is limited. Low numbers of calling males of this species are generally detected at sites (1–6 calling males) (Tyler and Anstis 1975; Anstis and Littlejohn 1996; Mahony *et al.* 2001; Spark and Townley 2020a, b; M. Mahony pers. comm. September 2021). However, during surveys in 1993-96 this species was found at several sites in larger numbers, the largest of which was in Barrington Tops NP, with 55 calling males detected (Anstis 1997). Two sites in Werrikimbe NP also recorded large numbers during the same survey period, with 24 and 36 males calling in a 400 and 500m transect, respectively (M. Mahony in litt. November 2021)]. These two sites have been revisited regularly since and a decline in detection has been observed, with the most recent survey in 2020 recording only one to two males calling (M. Mahony pers. comm. November 2021). A potential decline in abundance was also reported in the region around Bulga SF and Elands

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between surveys in 1977-80 and those conducted the early 1990s (Anstis and Littlejohn 1996; Anstis 1997).

Surveys conducted at 11 sites across the known distribution of the species during the spring and summer seasons of 2017 and 2018 found the average number of males calling at a site was 2.5, with a maximum number of six (M. Mahony pers. comm. October 2021). Recent survey conducted after the 2019–20 fires found only an average of one to two calling males at eight of the previously monitored sites (M. Mahony in litt. December 2021).

## **Ecology**

### Key habitat requirements:

*Litoria daviesae* is a habitat specialist typically found along upland streams at elevations above 400 m asl. The species has been recorded along streams in montane heathland and dry open forest on the tablelands, and through wet sclerophyll and rainforest vegetation on the edge of the escarpment of the Great Dividing Range (Mahony *et al.* 2001). It has also been recorded on streams through cleared pasture lands where streamside vegetation is retained (Lemckert and Mahony 2018).

The species is usually found adjacent to permanently flowing streams which often comprise areas of gentle flow with large pools mixed with faster flowing shallow sections with cascades and waterfalls (Mahony *et al.* 2001; McRae 2019). This species has rarely been recorded away from the riparian zone, indicating that they may depend on habitats within this zone for breeding and foraging. Nothing is known about habitat use outside of the breeding season (Mahony *et al.* 2001).

### Life History:

Breeding occurs from spring to early summer, mostly in shaded stream pools where there is less water flow (Anstis 2017). Both diurnal and nocturnal calling has been recorded. In the daytime males can be found calling hidden under rocks, in logs or within vegetation not far from the stream edge (Anstis and Littlejohn 1996). During the night males call from perched positions on ferns or broad-leaf shrubs 0.5–1.5 m above the water (Anstis and Littlejohn 1996). When calling, adult males can be found singly or in small groups along a stream at suitable sites (Anstis and Littlejohn 1996). Calling increases in intensity during or after light rain (Anstis 2017). The calls of *L. daviesae* and *L. subglandulosa* are similar (Anstis and Littlejohn 1996) and consist of a call sequence of about 5–7 repeated two part notes, the second part louder and slightly longer than the first (or-ak) (Anstis 2017).

Eggs are laid as a single cluster that is attached to a plant or rockface just below the water surface at a shaded slowly flowing section of a pool, or mid-stream (Anstis 2017). Eggs take 6–10 days to hatch (Anstis and Littlejohn 1996). Tadpoles can reach up to a length of 4.5 cm and are gold-brown in colour. They can be usually found on sand, amongst rocks or leaf litter at the sides of shallow slowly-flowing sections of the streams, feeding on silt and algae (Anstis and Littlejohn 1996). Tadpoles take three to four months to develop into frogs (Anstis 2017). There are no studies on the movement and dispersal of this species.

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## Generation length:

The longevity of *Litoria daviesae* is unknown but is estimated to be around 10 years and the minimum age of first reproduction is estimated to be three to four years for females (M. Mahony pers. comm. September 2021). Based on this information, an estimate of generation length is around six years.

## Threats

The main threats to *Litoria daviesae* are historic and ongoing loss, fragmentation and degradation of its native habitat due to agriculture and forestry activities; amphibian chytrid fungus; changed fire regimes; and climate change. It is also threatened by habitat destruction by introduced fauna and possible predation on eggs and tadpoles by introduced 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, particularly in the regions of the Comboyne Plateau and upper Manning River catchment (Mahony *et al.* 2001). Much of the remaining forest habitat where *Litoria daviesae* is distributed now falls within protected areas or state forest, however habitat degradation and fragmentation continue in some parts due to ongoing timber harvesting, disturbances affecting hydrological processes, degradation of water quality, altered fire regimes, feral animals and weed invasion (Mahony *et al.* 2001; NSW Scientific Committee 2002). The impact of these disturbances on the species is unknown, but from current knowledge of the species' ecology, including the likely requirement for vegetated riparian habitat for dispersal, any increase in habitat loss and fragmentation is expected to be highly detrimental. 'Clearing of native vegetation' is listed as a key threatening process in NSW under the BC Act.

### 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 2020).

Mapping of the extent and severity of the 2019–20 fires estimate that up to maximum of 43% of the distribution of *L. daviesae* was impacted to some extent by fire (with 9% at high severity; Legge *et al.* 2021). High intensity fires occurred across the more northerly parts of the species distribution including in Carrai Plateau and Werrikimbe NP. To the south however, only small areas of Barrington Tops NP and SRA were burnt (DPIE 2021a).

There is little information available on the impact of fires on Australian frogs. Adult and juvenile *L. daviesae* may be directly killed as a result of forest fires, however due to their association with streams and riparian habitat, they are likely to have sought shelter in the water or under bank crevices, well protected from the fire. However, there are many indirect ways in which fire could profoundly impact frog populations, including the consequential changes in hydrology, water chemistry, sedimentation of streams, changes in soil structure and groundwater seepage, increased temperatures and evaporation in habitat where canopy loss is significant, all of which

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affect the habitat and microclimate of frogs (Bamford and Roberts 2003; Durnham *et al.* 2007).

Wildfire may also impact frog population connectivity and genetic diversity. A study examining the impacts of the 2009 'Black Saturday' bushfires in Victoria on the population of *Litoria ewingii* and *L. papaewingi*, found that both of these common and abundant frog species were significantly more inbred after the fires as a result of decreased habitat connectivity, limiting movement between populations and preventing recolonisation post-fire (Potvin *et al.* 2016).

Post 2019-20 surveys of *L. daviesae* across known sites that had experienced high severity fires (including Werrikimbe NP) found detection of the species to be low, with zero up to only one calling male recorded per 50m transect, compared to surveys in 2017 and 2018 when an average of two (up to maximum of four) individuals were detected in 50 m transect (M. Mahony pers. comm. October 2021). The species was detected post-fire at seven low to moderately burnt sites via the FrogID project (Rowley *et al.* 2019; Rowley and Callahan 2020). The population trend of this species unknown, but these survey results infer a possible population decline including potentially a loss of populations. It is unknown if this apparent decline is all a direct result of the fires (M. Mahony pers. comm. October 2021). The closely related species *L. subglandulosa*, has been recorded at 27 sites that were impacted by moderate to high severity fires during the summer of 2019-20 via the FrogID project (Rowley *et al.* 2019; Rowley and Callahan 2020). Although the species is still present at many fire impacted sites, post-fire surveys indicated a reduction in the number of males calling as compared to surveys prior to the fires (M. Mahony pers. comm. November 2021).

The impacts of fire long-term for this species are unknown, but given 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.

'High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' is listed a key threatening process under the NSW Biodiversity Conservation Act.

### Climate Change

Under current climate change projections, it is expected that minimum and maximum temperatures in the North Coast and New England North West regions will increase in the near future by 0.4–1.0°C and the regions will experience more hot days (over 35°C) (DPIE 2020a; 2020b). 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; 2020b). 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 Rainforest of Australian World Heritage Area indicate an increase in temperature and a decrease in humidity and cool season rainfall (Dowdy

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2018; Narsey *et al.* 2020). Models also suggest an increase in the base height of clouds in a warmer future, further intensifying drying trends.

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).

Climate change is considered a significant threat to the persistence of *L. daviesae* and is predicted to further isolate subpopulations and reduce the available suitable habitat at lower elevations. Changes in temperature or precipitation have the potential to influence many aspects of amphibian reproduction, including timing of breeding and developmental rates. In addition, climate change may alter the habitats of stream dwelling frogs including hydrology and riparian vegetation and make them vulnerable to being dislodged in high flows. Climate change may also influence food availability for frogs and influence how diseases such as chytridiomycosis are manifested (Blaustein *et al.* 2010; DOEE 2016).

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).

'Anthropogenic Climate Change' is listed a key threatening process under the NSW Biodiversity Conservation Act.

### Disease – Chytridiomycosis caused by amphibian chytrid fungus

*Litoria daviesae* is susceptible to infection by 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). In Australia, chytridiomycosis has been directly implicated in the extinction of at least four species and population declines of at least 10 others (DOEE 2016).

*Litoria daviesae* inhabits cooler upland environments where the growth and impacts of the amphibian chytrid fungus appear to be greatest (Berger *et al.* 1999). In addition, frog species that have aquatic larvae associated with streams and spend a large proportion of their time in or adjacent to streams are more likely to be infected with the amphibian chytrid fungus and suffer population declines compared to other species (Williams and Hero 1998, McDonald and Alford 1999; Kriger and Hero 2007).

Amphibian chytrid fungus has been recorded in several populations of *L. daviesae* across its distribution (M. Mahony unpublished data) and is suspected to be responsible for declines in some sites (M. Mahony *in litt.* November 2021), Chytridiomycosis was recorded for the first time in a population of this species during a survey in December 2020, in Werrikimbe NP, when sick and moribund frogs were discovered (M. Mahony *in litt.* November 2021), however, it is unknown how widespread this species susceptibility to the disease is across its distribution or how it impacts populations (Stockwell *et al.* 2016; M. Mahony *in litt.* November 2021).

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"Infection of frogs by amphibian chytrid causing the disease chytridiomycosis" is listed as a key threatening process in NSW under the BC Act.

## Invasive Fauna

Feral pigs (*Sus scrofa*) may be a threat to this species (M. Mahony pers. comm. September 2021). Pigs may prey directly on adults and nests 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 this species could be exacerbated during periods of drought as they search out the limited areas of water. Feral pigs are currently known to occur in many areas within *L. daviesae* distribution including Werrikimbe NP and Barrington Tops NP (NPWS 2005; 2010).

Feral horses can significantly alter stream bank structure and stability, through trampling and overgrazing, leading to erosion, increased sedimentation and potentially the spread of weeds (NPWS 2010; Driscoll *et al.* 2019) and have been shown to reduce breeding habitat for amphibians (Foster and Scheele 2019). Feral horses (*Equus caballus*) are known to be impacting the riparian zones which *L. daviesae* inhabit within Barrington Tops NP (NPWS 2010). However, a study by McRae (2019) found that at the current feral horse population size there was no negative association between horse damage and presence of *L. daviesae*. Nevertheless, an increase in horse populations would likely impact stream depth and vegetation cover that would be detrimental to the presence of this species (McRae 2019).

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 (NPWS 2005; 2010). 'Predation by the European red fox (*Vulpes vulpes*)' and 'Predation by feral cats (*Felis catus*)' are currently listed as a key threatening process in NSW under the BC Act.

## Predation by Introduced Fish

*Litoria daviesae* tadpoles and eggs are likely to be consumed by introduced fish, including Carp (*Cyprinus carpio*), Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*), and Plague Minnow (*Gambusia holbrooki*), which co-occur with this species (Gillespie and Hero 1999; Mahony *et al.* 2001). Many of the streams within the species' range continue to be stocked with Rainbow and Brown trout, including streams in Barrington Tops (Howell and Creese 2010; NPWS 2010; DPIE 2021b). Introduced fish such as trout and Plague Minnow have been implicated in the decline of several stream-dwelling frogs (Morgan and Buttemer 1996; Pyke and White 1996; Webb and Joss 1997; Gillespie and Hero 1999; Gillespie 2001).

'Predation by *Gambusia holbrooki* Girard, 1859 (Plague Minnow or Mosquito Fish)' is listed as a Key Threatening Process under the Act.

## Weeds

Post-fire weed invasion may be a threat for *Litoria daviesae* in burnt habitat, however there have been no studies to determine their impact. Weeds may affect the species

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by altering habitat structure and possibly subterranean hydrology and water availability, as well as potentially exacerbating future fire threat.

## **Assessment against IUCN Red List criteria**

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

### *Criterion A Population Size reduction*

#### Assessment Outcome: Data Deficient

Justification: The population size of *Litoria daviesae* is unknown and information regarding population trends of the species is limited, with all observations restricted to a small number of calling males. There have, however, been some observations of the species declining or absent in some sites. Anstis (1997) reported a reduced population abundance in the region around Bulga SF and Elands in 1996, as compared to results in 1977. In addition, there has been a reduced detection in the number of calling males in sites within Werrikimbe NP over time since sizeable numbers were recorded during surveys in the early 1990s. Post-fire 2019-20 surveys across the species distribution recorded lower number of calling males than previous surveys (in 2017 and 2018) and failed to detect the species at some previously recorded sites in the north of the species distribution. It is estimated that overall the population has experienced a decline in abundance of approximately 20% (possibly up to 40%) since the early 1990s (M. Mahony pers. comm. September 2021).

To be listed as threatened under Criterion A, the species must have experienced a population reduction of <sup>3</sup>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 *Litoria daviesae* against this criterion.

### *Criterion B Geographic range*

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

Justification: *Litoria daviesae* has a limited distribution. It occurs in a narrow band on the eastern edge of the tablelands and escarpment of the Great Dividing Range, with a latitudinal range of about 150 km and a narrow east-west distribution.

Extent of occurrence (EOO) for all known records for the species was estimated to be 11 305 km<sup>2</sup>, 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<sup>2</sup> qualifies under the Vulnerable threshold.

AOO - The area of occupancy (AOO) for all records was estimated to be 608 km<sup>2</sup>, based on 2 x 2 km grid cells, the scale recommended for assessing area of



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occupancy by IUCN (2019). A species with an AOO of less than 2 000 km<sup>2</sup> qualifies under the Vulnerable threshold.

*Litoria daviesae* 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: Habitat is severely fragmented, and number of locations is ≤5.

Thus, the species is considered to be severely fragmented.

There are two threat-defined locations with the main threat being disease.

Justification: Although *L. daviesae* 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). Ongoing threats such as adverse fire regimes, climate change and invasive fauna are also likely to affect the future extent of the preferred habitat of this species.

There are considered to be either:

- 2 threat-based 'locations' with disease or fire being the main threat (M. Mahony pers. comm. September 2021). Or
- 1 threat-based location with climate change being the main threat.

- 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 (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, disease, invasive fauna species, adverse fire regimes and climate change.

- 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 *Litoria daviesae*.

*Criterion C Small population size and decline*

Assessment Outcome: Data Deficient

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Justification: The population size of *Litoria daviesae* is unknown and there has been no comprehensive surveying of this species, 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 generations (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: There are no data on population declines over any relevant time frames to determine whether or not there is a continuing decline in population size.

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

Assessment Outcome: Data Deficient

Justification: There is no information for this species for which to determine whether or not there is a measurable continuing decline in population size.

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

- a (i). Number of mature individuals in each subpopulation  $\leq 50$  (CR);  $\leq 250$  (EN) or  $\leq 1000$  (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 is 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 met

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Justification: The population size of *Litoria daviesae* is unknown. The AOO is not considered to be very small (<20 km<sup>2</sup>).

To be listed as Vulnerable under D, a species must meet at least one of the two following conditions:

D1. Population size estimated to number fewer than 1,000 mature individuals

Assessment Outcome: Data Deficient

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

D2. Restricted area of occupancy (typically <20 km<sup>2</sup>) 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: Not met

Justification: AOO has been calculated to be 608 km<sup>2</sup> and so is not considered to be very restricted. Although there is estimated to be less than five threat-based locations (either two locations, with disease or fire being the main threat, or one location with climate change 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**

### 2019–20 bushfire response

- As per guidance developed by Southwell *et al.* (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 September to March.
- 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. Note that herbicide formulations can be toxic to frogs and tadpoles, particularly if they contain glyphosate and surfactants (Mann *et al.* 2003).

## Conservation and management priorities

### 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 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 Davies' Tree 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.
- Manage any hydrological disturbances and maintain environmental water levels to meet species requirements.

### 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. 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.
- Assess the impact of introduced weeds on habitat suitability for Davies' Tree 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).
- Evaluate possible predation of tadpoles by introduced fish including Carp, trout and Mosquito Fish. Undertake predator surveys at survey sites. Reduce pest density and maintain low levels.
- Monitor and control damage to riparian areas by feral pigs. Control pig numbers and fence key sites, where feasible.
- Investigate the impact of feral horses in upland swamps on the breeding habitat of Davies' Tree Frog. If the impact is shown to be significant, develop a strategy for control and fence key sites, if feasible.

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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.

## Disease

- Collect and analyse samples from all monitoring programs for the species, to test for the presence of chytrid fungus, the susceptibility of the Davies' Tree Frog 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.

## Stakeholder Engagement

- Provide input into the various impact assessment and planning processes on measures to protect Davies' Tree Frog and its habitat. These include water resource plans, park management plans and environmental impact assessments
- Collaborate with land managers to protect and manage forest areas where the species occurs, or which contain potential habitat for the species, from threats due to disease and invasive species.
- Inform the public about the status of the species.

## 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 September to January.
- Regular monitoring should be undertaken for a small number of subpopulations from September to January when male frogs are known to call. Note: Frogs should be disturbed at breeding sites under any circumstances.
- Broad scale 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 previously unknown.
- Undertake targeted surveys in poorly surveyed areas and environments with potential characteristics as refuges from the amphibian chytrid fungus.
- Conduct habitat monitoring, including water quality and macro-invertebrate richness to determine the effect of stream pollution on target species.

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## Information and research priorities

- Investigate the ecological requirements (e.g. habitat use, diet, movement patterns) and life history characteristics of the species relevant to its persistence.
- Investigate factors influencing and necessary to maintain metapopulation viability. Develop a greater understanding of the nature of habitat and population connectivity to inform management of viable populations.
- 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.
- 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 Davies' Tree Frog to better inform how to apply existing or new management actions relevant to the recovery. This includes knowledge on:
  - the susceptibility of Davies' Tree 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 on 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 fragmented and isolated.
- Improve understanding of the impacts of feral pigs and horses on the Davies' Tree Frog.

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## Expert Communications

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## Appendix 1

### Assessment against Biodiversity Conservation Act 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

<b>(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:</b>			
	(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.
<b>(2) - The determination of that criteria is to be based on any of the following:</b>			
	(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)]

<b>The geographic distribution of the species is:</b>			
	(a)	for critically endangered species	very highly restricted, or
	(b)	for endangered species	highly restricted, or
	(c)	for vulnerable species	moderately restricted,
<b>and at least 2 of the following 3 conditions apply:</b>			
	(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**

<b>The estimated total number of mature individuals of the species is:</b>		
(a)	for critically endangered species	very low, or
(b)	for endangered species	low, or
(c)	for vulnerable species	moderately low,
<b>and either of the following 2 conditions apply:</b>		
(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: Does 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.
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