

# THREATENED SPECIES SCIENTIFIC COMMITTEE

Established under the *Environment Protection and Biodiversity Conservation Act 1999*

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The Minister approved this conservation advice and retained this species in the Endangered category, effective from 19/10/2021

## Conservation Advice

### *Mixophyes fleayi*

Fleay's Frog

#### **Taxonomy**

Conventionally accepted as *Mixophyes fleayi* Corben & Ingram, 1987.

#### **Summary of assessment**

##### **Conservation status**

Endangered: Criterion B2(a)(b)(i,ii,iii,iv,v)

The highest category for which *Mixophyes fleayi* is eligible to be listed is Endangered.

*Mixophyes fleayi* has been found to be eligible for listing under the following categories:

Criterion 2: B2(a)(b)(i,ii,iii,iv,v): Endangered

Criterion 3: C1: Vulnerable

Species can be listed as threatened under state and territory legislation. For information on the listing status of this species under relevant state or territory legislation, see

<http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>

#### **Reason for conservation assessment by the Threatened Species Scientific Committee**

Fleay's Barred Frog was listed as Endangered under the predecessor to the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) the *Endangered Species Protection Act 1992* (ESP Act) and transferred to the EPBC Act in July 2000.

This advice follows assessment of new information provided to the Committee to change the listing status of Fleay's Barred Frog.

#### **Public consultation**

Notice of the proposed amendment and a consultation document was made available for public comment for 33 business days between 10 June 2020 and 24 July 2020. Any comments received that were relevant to the survival of the species were considered by the Committee as part of the assessment process.

#### **Species/sub-species information**

##### **Description**

Fleay's Barred Frog is a large burrowing frog endemic to mid-eastern Australia. Females are larger than males, having a snout-to-vent length (SVL) of over 90 mm and weighing over 100 g. Males reach 80 mm (SVL) and weigh up to 59 g. The skin is finely granular above and smooth below. The dorsal surface is light to dark brown with indistinct darker marbling. Typical of barred frogs, an irregular, dark, vertebral stripe is present. The Y-shaped stripe commences between the eyes and extends to the vent, sometimes breaking up into a series of blotches along the midline. The flanks are grey-brown, fading to yellow posteriorly, and overlaid by a series of black spots. The ventral surface is typically yellow. The snout is steeply sloped and blunt with an irregular dark band running from the nostril, through the eye, to a point behind the large, oval tympanum. The eyes are prominent with a dark purple patch visible beneath. The upper part of the iris may be straw-brown through light blue to silvery-white. The pupil is vertical. The upper lip

is usually mottled brown with one or more purplish-brown blotches. A vocal sac is present in adult males. The thighs are grey-brown with seven or eight narrow, black cross-bands. The hands are not webbed, while the feet are about one-third webbed. The tips of the fingers and toes do not have disc-like pads. The soles and palms are black. Males develop dark brown nuptial pads on the prepollex, first finger, and sometimes the second finger.

Fleay's Barred Frog is similar to other *Mixophyes* species, particularly *M. balbus* (Stuttering Frog), from which it can be distinguished by the presence of mottling on the flanks as well as differences in the male advertisement calls. During spring and summer, the male Fleay's Barred Frog makes a throaty "ok-ok-ok-ok-ok" or a long rasping "arrrrk" call from leaf litter beside streams. The description of the adult is drawn from Corben & Ingram (1987); Meyer et al. (2001); Hines (2012); Cogger (2014); and Anstis (2017).

Tadpoles are large (growing to 100 mm in total length) with a fusiform body and a thick, muscular tail that is twice the length of the body. The tail fins are opaque and have scattered dark spots and splotches. The limb buds and vent tube lie within a translucent 'skirt' at the base of the tail. From above, tadpoles are almost black in early stages, and from below they are a silver-grey colour. A fine layer of gold or rusty brown pigment gradually covers the entire body as the tadpole grows (except for a darker patch across the base of the body). The intestinal mass is fully obscured, with the heart and gills barely visible. Eyes are positioned dorsolaterally, and the iris is golden. The mouth is sub-terminal with a large oral disc surrounded by papillae. The spiracle is sinistral and opens lateroventrally near the midpoint of the body. The description of the tadpole is drawn from Meyer et al. 2001; and Anstis 2017.

## Distribution

Fleay's Barred Frog is patchily distributed in montane areas in far south-east Queensland and far north-east New South Wales (NSW). The species has been recorded from the Conondale Range, Queensland (40 km inland from the Sunshine Coast) to Yabbra National Park, NSW (110 km inland from Byron Bay) (Hines et al. 1999; Doak 2005; Stratford et al. 2010; Anstis 2017) and as far west as Tooloom National Park, NSW (D Newell 2020. pers comm 15 April). Within this narrow range, it is known from 30 scattered sites (Newell et al. 2013) mostly within National Parks (NP) (Hines 2012).

Mitochondrial DNA analysis conducted by Doak (2005) identified two distinct areas of genetic endemism either side of the Brisbane River Valley, with isolation of the Conondale Range in the north from all other subpopulations to the south. This regional isolation could date back to rainforest fragmentation during the Pliocene (5.3 million to 2.14 million years ago). Doak (2005) proposed that these divergent and geographically isolated lineages are separate Evolutionarily Significant Units warranting independent conservation and management actions.

In Queensland, Fleay's Barred Frog is known from Conondale NP, Lamington NP, Springbrook NP, Main Range NP, Mount Barney NP, Adjibilly Nature Refuge and from private properties in the headwaters of Tallebudgera Creek and Condamine River. During the 1970-1990s, the species declined and disappeared from some previously known sites, largely as a result of disease (later identified as chytridiomycosis) (Newell et al. 2013; Newell 2018). Surveys did not record Fleay's Barred Frog in the Mount Tamborine area, the Bunya Mountains, and downstream sites in the Conondale Range (Goldingay et al. 1999; Hines & the South-east Queensland Threatened Frogs Recovery Team 2002; Hines 2012). Whether the species declined at other sites is difficult to assess due to a lack of survey data before the early 1990s. However, the very low numbers recorded from many well surveyed sites in the late 1990s to early 2000s suggest that this may have occurred (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002).

Fleay's Barred Frog is also thought to have declined in NSW, with surveys (1995–2000) finding the species restricted to a number of disjunct sites within its former distribution. The species was recorded at sites within Border Ranges NP, Tooloom NP, Yabbra NP, Wollumbin NP, and Nightcap NP. However, subsequent searches failed to find the species at some previously

populated sites within these locations, including Sheepstation creek (Border Ranges NP) and Mt Warning (Wollumbin NP) (DPIE 2000).

Following this decline, Fleay's Barred Frog was thought to have been generally recovering in Queensland during the late 1990s and early 2000s (H Hines 2020 per. comm 14 May) and a recovery at some sites in NSW had been demonstrated. Mark-recapture studies by Newell et al. (2013) showed recovery at Brindle Creek (Border Ranges NP) and Tunttable Falls (Nightcap NP) over a seven-year period (2001-2008). At Brindle Creek, numbers increased tenfold (from 6 to 60 individuals), and at Tunttable Falls, numbers increased threefold (19 to 57 individuals). Quick et al. (2015) showed a subpopulation at high elevations in the Border Ranges NP had remained relatively stable over a 10-year period, and at Terania Creek (Nightcap NP) Fleay's Barred Frog has slowly returned following its disappearance in the early 1990s.

## **Relevant biology/ecology**

### *Habitat*

Fleay's Barred Frog is a ground-dwelling amphibian inhabiting montane rainforest and adjoining wet sclerophyll forest habitat (Doak 2005; Anstis 2017). This species mostly occurs at higher altitudes (above 400 m) but has been found at elevations ranging from 100–1000 m (Goldingay et al. 1999; Hines & the South-east Queensland Threatened Frogs Recovery Team 2002).

Fleay's Barred Frog is an obligate stream breeding species relying on permanent and semi-permanent freshwater streams for breeding habitat (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002). It's habitat is usually defined in terms of stream environments, but terrestrial habitat may be of greater importance to species recovery, with females spending most of their time (often at a significant distance) away from breeding sites, including along ridge tops (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002; Doak 2005). Also, Newell et al. (2013) identified longevity of adults as central to buffering the population from periods of low recruitment and of greater importance than increased egg or tadpole survival in streams.

### *Breeding*

Breeding occurs under suitable conditions from July to March, with males calling at dusk and into the night from rock or debris perches in or adjoining streams, as well as from under leaf litter near streams (O'Reilly & Hines 2002, Hines 2012). Fleay's Barred Frog can form large breeding aggregations where males physically compete for access to females. For successful breeding, the species has specialised site requirements with favourable environmental conditions that are thought to reduce the chance of egg predation from fish and large tadpoles. Stratford et al. (2010) observed that the number of individuals comprising a chorus was highly variable and significantly related to ambient temperature and stream height, which (with rainfall, humidity, and wind intensity) accounted for most of the variation in aggregation size. Cooler conditions reduce breeding activity, and Fleay's Barred Frog does not appear to breed during or immediately after heavy rain. Rather, the species breeds shortly after stream flow has slowed towards basal flow, with egg deposition only occurring where shallow stream riffles form. A non-foamy egg mass of up to 1000 eggs is deposited into a rounded nest depression in the substrate or occasionally directly onto bedrock (Knowles et al. 2015). Tadpoles are long-lived and present year round at some sites, taking six months to two years to complete their development (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002; Hines 2012).

### *Behaviour*

Male Fleay's Barred Frogs display high levels of philopatry, staying in the leaf litter around established breeding sites, while females and sub-adults punctuate small, localised movements with larger movements, travelling many hundreds of metres away. These movements may allow females to disperse between neighbouring breeding sites. However, genetic analysis on mitochondrial DNA has shown subpopulations separated by as little as two km to be genetically significantly different from each other, indicating low gene flow (interbreeding) between sub-catchments (Doak 2005).

Gene flow is believed to be restricted by geographical distance, the presence of potential landscape barriers, the availability of interconnecting suitable habitat, and environmental

conditions. Dry, lowland areas are thought to act as effective barriers to dispersal, and females are believed to move between sub-catchments along shared mountain ridge-tops, with the extent of the shared boundary increasing the probability and magnitude of gene flow. However, females often display a preference for familiar breeding sites, returning from surrounding ridge-tops to the same site in successive breeding seasons. This apparent breeding site fidelity by both males and females reduces the likelihood of Fleay's Barred Frog successfully colonising or recolonising vacant habitat in the event of subpopulation extirpation (Doak 2005).

The diet of Fleay's Barred Frog is not known. Other *Mixophyes* species are known to feed on arthropods, arachnids, amphipods, centipedes, millipedes, gastropods, nematodes, skinks and other anuran species (Lemckert & Shoulder 2007; Martin & Murray 2011). The diet of the tadpole is poorly known, but they have been observed feeding on algae, detritus, and carrion (Anstis 2002, Meyer & Hines 2004).

## Threats

**Table 1:** Threats impacting Fleay's Barred Frog in approximate order of severity of risk, based on available evidence

Threat factor	Threat type and status	Evidence base
Habitat loss and fragmentation		
Vegetation clearance/habitat fragmentation	Known current	<p>Large-scale clearing has resulted in much of the remaining subtropical montane rainforest along the Great Dividing Range of south-east Queensland and north-east NSW being reduced to a discontinuous arc (Hagger et al. 2013).</p> <p>Through mapping habitat quality, measuring metapopulation capacity, and predicting occupancy patterns of Fleay's Barred Frog across north-east NSW, Drielsma and Ferrier (2009) predicted that the species will likely be restricted to just five locations, each separated by approximately 20 km from the next nearest subpopulation. Connecting habitat was deemed to be of low value and was evaluated to have a high metapopulation extinction risk.</p> <p>Historical fragmentation has occurred in the Queensland population. Distinct areas of genetic endemism are identified either side of the Brisbane River Valley, with the Conondale Range subpopulation isolated in the north from all other subpopulations (Doak 2005).</p> <p>This fragmentation and isolation of subpopulations across the distribution range, together with the low dispersal ability (and associated poor recolonisation potential) of the species (Doak 2005), reduces the likelihood of recovery from extreme events, including bushfires and disease (Drielsma &amp; Ferrier 2009; Hagger et al. 2013; Newell et al. 2013).</p> <p>More generally, upstream clearing of habitat and disturbances, such as timber harvesting and urban development, may reduce water quality and flow</p>

		regimes. Increased sedimentation in streams can result in filling of crevices in stream substrates, reducing the availability of suitable oviposition sites or refugia for tadpoles (Welsh & Ollivier 1998).
Climate Change		
Increased temperature intensity/frequency and change to precipitation patterns	Known current	<p>Climate change is expected to cause a pronounced increase in extinction risk for frog species over the coming century (Hagger et al. 2013; Pearson et al. 2014). Climate projections for eastern Australia include reduced rainfall, increased average temperatures, and more frequent droughts. These conditions will increase the scale, frequency and intensity of wildfires (CSIRO 2007; CSIRO &amp; Bureau of Meteorology 2015) and could negatively impact the duration and seasonality of stream breeding sites (Lemckert and Penman 2012).</p> <p>Impacts from climate change are compounded by Fleay's Barred Frog's restricted area of occupancy, low population density at sites, prevalence at higher altitudes (above 400 m), short generation length (four–five years), and large body size. These variables are identified as increasing the risk of local extirpation (Oza et al. 2012; Hagger et al. 2013; Pearson et al. 2014) and are amongst the strongest predictors of species' vulnerability to climate change (Pearson et al. 2014).</p> <p>Tanner-McAllister et al. (2018) developed conceptual models for four World Heritage National Parks to predict the likely impact to stream-dwelling frogs from climate change. The models showed a higher probability of a decreasing population under increasing severity of climate change, even under a 'good' management scenario. An increase in wildfire events was found to be the most detrimental impact, giving a higher probability of a decreasing population under both moderate and substantial climate change models, with the most severe scenario resulting in over a 50 % probability that there would be a population decrease.</p>
Increased intensity/frequency of bushfire	Known current	<p>Localised extirpation of frogs has been observed through wildfire events. Penman et al. (2006) observed that temperate Australian frog species generally have a critical thermal limit of 34–38 °C. Burrowing by Fleay's Barred Frog is restricted to the leaf litter and very upper top-soil, providing little protection from the heat generated by wildfire. At particular risk are adult female frogs who spend most of their time (often at a significant distance) away from stream breeding sites, including along ridge tops (Hines &amp; the South-east Queensland Threatened Frogs Recovery Team 2002; Doak 2005).</p>

		<p>Wildfire can adversely affect stream breeding habitat by increasing water temperature, altering water chemistry (Lyon &amp; O'Connor 2008), and creating sediment/ash runoff 'slugs' that can form in waterways following rainfall (Lyon &amp; O'Connor 2008; Alexandra &amp; Finlayson 2020). These slugs can fill in crevices in stream substrates, reducing the availability of refugia for tadpoles (Welsh &amp; Ollivier 1998), and promote toxic algal blooms (Alexandra &amp; Finlayson 2020) that can deoxygenate the water and cause egg and tadpole death. Sediment slugs can impact aquatic ecosystems up to 80 km downstream of burnt areas (Lyon &amp; O'Connor 2008), greatly increasing the impact to stream dependent species outside of the immediate burnt area. Impacts from these slugs can persist for a significant period of time. Following the 2006-07 fires in Victoria (which burnt over 32 % of the Gippsland Lakes' catchment), rains washed an extremely high nutrient load into the lakes, which prompted a <i>Synechococcus</i> algal bloom that persisted until the winter of 2008 (Alexandra &amp; Finlayson 2020).</p> <p>In 2019-20, following years of drought (DPI 2020), catastrophic wildfire conditions culminated in fires that covered an unusually large area of eastern and southern Australia. An analysis by a team from the National Environmental Science Program (NESP) Threatened Species Recovery (TSR) Hub showed that 18 % of the distribution of Fleay's Barred Frog was affected by these fires (with 3 % burnt in high to very high severity fire), and the estimated proportional population change for this species from pre-fire levels to 1 year after the fire was an overall decline of 7 % from pre-fire levels, but that the decline could be as large as 35 % (bound of 80 % confidence limits) (Legge et al. 2021). This sort of event is increasingly likely to reoccur as a result of climate change.</p>
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Disease

<p>Chytridiomycosis caused by chytrid fungus</p>	<p>Known current</p>	<p>Chytridiomycosis is an infectious disease caused by the amphibian chytrid fungal pathogen <i>Batrachochytrium dendrobatidis</i> (<i>Bd</i>). Infected populations exhibit diverse susceptibility to <i>Bd</i>. Some species do not exhibit any apparent symptoms while others are extremely vulnerable, resulting in mass die-off and extinction (DOEE 2016).</p> <p>Studies have shown that Fleay's Barred Frog is impacted by <i>Bd</i>, with the pathogen identified as the cause of death of individuals from a number of sites (Berger et al 1998, Murray et al 2010). Tadpoles are known to carry <i>Bd</i> in their mouthparts, and a</p>
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		<p>study by Hines (2012) showed the prevalence in the tadpole population to be close to 100 % in the Main Range NP. Ingram &amp; McDonald (1993) suggested that species abundance dropped by up to 90 % across the geographic range, largely as a result of disease (later identified as chytridiomycosis).</p> <p>Eradicating <i>Bd</i> is difficult. Some amphibian species are reasonably tolerant, acting as a natural reservoir and spreading the pathogen, which persists even at low host densities. There is no evidence that <i>Bd</i> has disappeared from any location in eastern Australia (Voyles et al. 2009; Newell et al. 2013).</p> <p>However, recovery of Fleay's Barred Frog at sites has been shown in the presence of <i>Bd</i> (Hines 2012; Newell et al. 2013). Mark-recapture studies found the number of individuals in two separate sites increased three-tenfold over a seven-year period (Newell et al. 2013). In addition, Quick et al. (2015) showed a subpopulation at high elevations in the Border Ranges in NSW has remained relatively stable over a 10-year period despite the presence of <i>Bd</i>.</p> <p>Despite signs of recovery, Fleay's Barred Frog may still be vulnerable to future declines from <i>Bd</i>. Monitoring reveals the species remains absent from some historical locations, with other subpopulations characterised by low abundance (Newell et al. 2013; Newell 2018).</p>
Invasive species		
Habitat damage by feral pigs ( <i>Sus scrofa</i> ).	Known current	<p>Feral pigs are found in all states and territories of Australia, particularly in association with wetlands and river systems (DOEE 2017a). Large areas of habitat (containing known Fleay's Barred Frog subpopulations) has been damaged by feral pigs in the Conondale NP, Main Range NP, and Yabbra NP.</p> <p>Although there may be direct predation by pigs, the greatest effect is likely to be the impact of increased sediment load on embryos and tadpoles (Hines &amp; the South-east Queensland Threatened Frogs Recovery Team 2002). By wallowing and rooting, feral pigs modify streamsides and increase erosion (DOEE 2017a). The increased sediment fills crevices in stream substrates and reduces the availability of suitable oviposition sites or refugia for tadpoles (Welsh &amp; Ollivier 1998). This is likely to be a significant threat to Fleay's Barred Frog as tadpoles take between six months to two years to complete development (Hines &amp; the South-east</p>

		Queensland Threatened Frogs Recovery Team 2002; Hines 2012).
Habitat damage by domestic stock	Known current	Areas of habitat have been damaged by domestic cattle trampling in Lamington NP and Main Range NP, with effects on water quality similar to those described above for feral pigs (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002). However, there has been successful fencing of streams at these two locations, with marked improvements in water quality and habitat (H Hines 2020. pers comm 14 May).
Invasive weeds	Potential current	<p>Mistflower (<i>Ageratina riparia</i>), Crofton Weed (<i>A. adenophora</i>), and Lantana (<i>Lantana camara</i>) are highly invasive weeds that occur along wet forest stream habitat. The effect of these weeds is not known, but they may reduce the area of sites suitable for egg laying (Hines &amp; the South-east Queensland Threatened Frogs Recovery Team 2002; Hines 2012).</p> <p>Changes to invertebrate assemblages brought about by exotic plant invasion may also impact Fleay's Barred Frog by altering the availability and composition of invertebrates, which are an important component of the diet of <i>Mixophyes</i> species (Lemckert &amp; Shoulder 2007; Martin &amp; Murray 2011).</p>
Predation by introduced and native species, including feral cats ( <i>Felis catus</i> ), <i>Cherax destructor</i> (Freshwater Yabby), and introduced fish species.	Suspected current	<p>The extent of predation by the feral cat on Fleay's Barred Frog is unknown. However, a study by Woinarski et al. (2020) estimated that nearly 100 million frogs are killed annually in Australia by the feral cat. Compounding this predation rate, in the aftermath of a fire, survivors may be isolated in an environment without shelter (leaf litter) and thereby become far easier to catch (Leahy et al. 2015; McGregor et al. 2015). In addition, the number of predators attracted to the area (Hradsky et al. 2017) and predator activity (Leahy et al. 2015) increase where habitat has been modified through frequent or intense burning.</p> <p>The presence of the Freshwater Yabby in virtually all coastal drainage systems in NSW has the potential to cause the local extirpation of fragmented subpopulations of Fleay's Barred Frog. Predation on Fleay's Barred Frog by the Freshwater Yabby has not been observed but known yabby behaviour includes stalking and hunting for frogs and tadpoles. Fleay's Barred Frog breeds in streams that are suitable for Freshwater Yabby invasion and are considered at high risk from this species. In addition, Fleay's Barred Frog</p>

		<p>lays eggs in a single mass, making them more susceptible to being eaten by the Freshwater Yabby (Coughran &amp; Daly 2012).</p> <p>Limited research has been carried out in Australia on the impact of introduced fish upon amphibian assemblages. However, Fleay's Barred Frog (as an obligate stream breeder) is a species identified as likely to be affected by exotic fish such as the Plague Minnow (<i>Gambusia holbrooki</i>). Fish are known to be a major influence on amphibian assemblage structure, and the introduction of exotic fish to aquatic systems has the potential to eliminate amphibian species through tadpole predation (Gillespie and Hero 1999).</p>
Habitat competition from invasive cane toad ( <i>Rhinella marina</i> )	Potential current	<p>The distribution and abundance of the cane toad has rapidly increased in Australia. Recent surveys have found individuals in high elevation rainforests of the Border Ranges. This region contains one of the largest known Fleay's Barred Frog subpopulations. The cane toad was not previously known from high altitude rainforests and was considered unlikely to occupy this habitat type (Newell 2011). In addition, following the 2019-20 bushfires, juvenile toads were observed moving through burnt rainforest in Lamington NP (H Hines 2020. pers comm 14 May).</p> <p>The cane toad's impact on Fleay's Barred Frog is not understood, but Newell (2011) proposed that it may compete for food and shelter sites. Also, the cane toad may act as a vector for introduced parasites and pathogens, including <i>Bd</i>.</p>
Human disturbance		
Visitors to National Parks	Known current	<p>With increased tourism to National Parks, there is a greater number of vehicles travelling through the distribution range of Fleay's Barred Frog increasing the chance of road-kill, particularly of females that sit on or move across roads on wet nights. As females are the main source of gene flow (Doak 2005), road-kill could reduce interbreeding between sub-catchments.</p> <p>Increased use of waterways by visitors can negatively impact on breeding success of Fleay's Barred Frog. Walking tracks that cross streams where frogs lay eggs are at risk of trampling, with damage to streambanks and direct mortality of eggs and tadpoles.</p>

**How judged by the Committee in relation to the EPBC Act criteria and regulations**

<b>Criterion 1. Population size reduction (reduction in total numbers)</b>			
Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	<b>Critically Endangered Very severe reduction</b>	<b>Endangered Severe reduction</b>	<b>Vulnerable Substantial reduction</b>
<b>A1</b>	≥ 90%	≥ 70%	≥ 50%
<b>A2, A3, A4</b>	≥ 80%	≥ 50%	≥ 30%
<p>A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.</p> <p>A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.</p> <p>A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [(a) cannot be used for A3]</p> <p>A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.</p>	<p>based on any of the following:</p> <ul style="list-style-type: none"> <li>(a) direct observation [except A3]</li> <li>(b) an index of abundance appropriate to the taxon</li> <li>(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat</li> <li>(d) actual or potential levels of exploitation</li> <li>(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites</li> </ul>		

**Evidence:**

**Not eligible.**

The generational length of Fleay’s Barred Frog is not known with certainty, but it is estimated to be four–five years. A capture-mark-recapture study by Newell et al. (2013) found individual frogs recurring throughout the six-year study, and Morrison et al. (2004) identified males ranging between two–six years and females three–eight years of age at breeding sites, with most males and females four years of age. This gives a timeframe of 12–15 years for this criterion, but this should be revised as ecological knowledge improves.

A substantial decline in the population (estimated at up to 90 percent) is believed to have occurred, predominantly in the 1970s to early 1990s (Ingram & McDonald 1993; Hines et al. 1999; Hines 2002; Newell et al. 2013; Quick et al. 2015; Berger et al. 2016), with chytridiomycosis identified as the likely cause (Laurance et al. 1996; Hero & Morrison 2004; Berger et al. 2016). This decline was not based on empirical data, due to a lack of surveys prior to the early 1990s (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002) but resulted in Fleay’s Barred Frog being listed as Endangered under the ESP Act in 2000 before being transferred to the EPBC Act (DoEE 2017b).

This decline took place over 30 years ago and is outside of the three generation timeframe. Also, Fleay’s Barred Frog was thought to have been generally recovering in Queensland (H Hines 2020 per. comm 20 April), and a recovery at some sites in NSW had been demonstrated (Newell et al. 2013). However, the resulting absence of the species from some historical locations, very low abundance at others, and isolation of remaining subpopulations (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002; Newell et al. 2013; Newell 2018), together with the low dispersal ability (and associated poor recolonisation potential) of the species (Doak 2005), has reduced the likelihood of species recovery from extreme events associated with climate change or disease (Drielsma & Ferrier 2009; Hagger et al. 2013; Newell et al. 2013).

Fleay’s Barred Frog is highly vulnerable to climate change, having physiological and ecological traits that confer both low resistance and low resilience to climate change. In particular, the

species' specialised breeding requirements may be impacted by reduced rainfall and increased temperatures, while an increased frequency and intensity of bushfires pose both a direct and indirect threat to the species (Hagger et al. 2013). A conceptual model by Tanner-McAllister (2018) showed a higher probability of a decreasing population under increasing severity of climate change, even under a 'good' management scenario.

The Fleay's Barred Frog population is likely reduced following the 2019-20 bushfires that burnt across southern and eastern Australia. The fires may have accelerated any population decline, through direct mortality, and the unfavourable post-fire conditions (loss of shelter, increased susceptibility to predators, and loss of prey), as well as a reduction in future recruitment (egg and tadpole death and breeding site degradation). An analysis by a team from the NESP TSR Hub shows that a significant proportion of the range of Fleay's Barred Frog was affected by these fires: three percent was burnt in high to very high severity fire, and a further 14 percent was burnt in low to moderate severity fire. A structured expert elicitation process was used to estimate the proportional population change for this species from pre-fire levels to immediately after the fire and then out to three generations after the fire, when exposed to fires of varying severity. These results, combined with the spatial analyses of fire overlap, suggest that one year after the fires, the species has experienced an overall decline of seven percent from pre-fire levels, but that the decline could be as large as 35 percent (bound of 80 percent confidence limits). After three generations, the estimate for the overall population decline relative to the pre-fire population is predicted to be eight percent, but potentially as much as 37 percent (bound of 80 percent confidence limit). For comparison, experts also estimated the population change over time in the absence of fire; by three generations, the overall population of Fleay's Barred Frog after the fire was estimated to be two percent lower than it would have been had the 2019-20 fire not occurred (Legge et al. 2021).

Early observations in Queensland are that areas of habitat with known subpopulations of Fleay's Barred Frog have burnt in Main Range NP, Lamington NP and Mount Barney NP. Significant mortality (particularly of juveniles and adult females) is likely in subcatchments where fire was widespread (e.g. Burnett Creek catchment, Mt Barney NP) or where it burnt along the stream banks or stream bed. Post-fire sediment slugs have been observed within occupied subcatchments, impacting oviposition site availability. Elsewhere, significant subpopulations in Lamington NP, Border Ranges NP, and the large subpopulation in the Dalrymple Creek catchment (Main Range NP) were not affected by the fires. In addition, fire severity mapping and ground-truthing has shown some relatively large unburnt areas of wet forests within the mapped burn extents in Mount Barney NP and Main Range NP (H Hines 2020. pers comm 14 May).

Given the signs of species recovery before the 2019-20 bushfires and the early indications that the population reduction following the fires is likely under 30 percent, the Committee has determined that the species is not eligible for listing in any category under this criterion as the past, current or future population declines are thought unlikely to exceed 30 percent in any three-generation period.

<b>Criterion 2. Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy</b>			
	<b>Critically Endangered Very restricted</b>	<b>Endangered Restricted</b>	<b>Vulnerable Limited</b>
B1. Extent of occurrence (EOO)	< 100 km <sup>2</sup>	< 5,000 km <sup>2</sup>	< 20,000 km <sup>2</sup>
B2. Area of occupancy (AOO)	< 10 km <sup>2</sup>	< 500 km <sup>2</sup>	< 2,000 km <sup>2</sup>
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented OR Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

### Evidence:

#### Eligible under Criterion 2 B2(a)(b)(i,ii,iii,iv,v) for listing as Endangered.

Fleay's Barred Frog is sparsely distributed along a small, mid-eastern section of the Great Dividing Range. Based on the mapping of point records for a 20-year time period (1999-2019) (obtained from state governments, museums and CSIRO) the Extent of Occurrence (EOO) has been estimated at 14 008 km<sup>2</sup>, and the Area of Occupancy (AOO) at 260 km<sup>2</sup>. The EOO was calculated using a minimum convex hull, and the AOO calculated using a 2x2 km grid cell method, based on the IUCN Red List Guidelines 2014. The EOO meets the threshold for listing as Vulnerable under sub-criterion B1 and the AOO meets the threshold for listing as Endangered under sub-criterion B2.

Due to large-scale clearing of lowland subtropical rainforest, much of the remaining habitat across the distribution range of Fleay's Barred Frog occurs in a discontinuous arc (Hagger et al. 2013), with species known from just 30 scattered sites (Newell et al. 2013) mostly within National Parks (Hines 2012). Subpopulations separated by as little as two km demonstrate significant genetic differences from each other, indicating a low level of interaction between individuals from different sites (Doak 2005). In addition, analysis conducted by Drielsma and Ferrier (2009) demonstrated that most of the NSW subpopulations are not viable. Mapping habitat quality and measuring metapopulation capacity, they predicted that occupancy of Fleay's Barred Frog would be reduced to just five sites, each separated by approximately 20 km from the next nearest subpopulation. Connecting habitat was deemed to be of low value and was evaluated to have a high metapopulation extinction risk. Similar fragmentation has occurred in the Queensland population, with two distinct areas of genetic endemism either side of the Brisbane River Valley identified by Doak (2005), with the Conondale Range subpopulation historically isolated in the north from all other subpopulations to the south. The Fleay's Barred Frog population is therefore considered severely fragmented, meeting sub-criterion (a), with a projected greater than 50 percent of AOO containing habitat patches that are not viable and with habitat patches separated by large distance (IUCN 2019).

Based on ongoing threats, the Fleay's Barred Frog population is projected to continue to decline in EOO, AOO, extent and quality of habitat, number of locations or subpopulations, and number of mature individuals, thereby meeting sub-criterion (b)(i,ii,iii,iv,v) (Hero et al. 2006). In particular, the small population size of Fleay's Barred Frog, already high degree of isolation of subpopulations (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002; Newell et al. 2013; Newell 2018), and the low dispersal ability (and associated poor recolonisation potential) of the species (Doak 2005), reduces the likelihood of recovery from extreme events, such as climate change or disease (Drielsma & Ferrier 2009; Hagger et al. 2013; Newell et al. 2013) (as identified in Criterion 1).

Disease and climate change have already greatly impacted Fleay's Barred Frog, with a decline in the 1970s to 1990s likely the result of *Bd*-infection (Ingram & McDonald 1993; Laurance et al. 1996; Hines et al. 1999; Hines 2002; Hero & Morrison 2004; Newell et al. 2013; Quick et al. 2015; Berger et al. 2016), and the impact of the 2019-20 bushfires suspected to be significant, with 18 percent of the distribution range of Fleay's Barred Frog overlapping with the fire-affected areas (see Criterion 1). Further, Fleay's Barred Frog is highly vulnerable to climate change, having the physiological and ecological traits that confer both low resistance and low resilience to climate change (Hagger et al. 2013; Tanner-McAllister 2018).

The Committee considers that the species' area of occupancy is restricted, and the geographic distribution is precarious for the survival of the species because its occurrence is severely fragmented, and continuing decline in extent of occurrence, area of occupancy, habitat, number of locations, and number of individuals may be inferred or projected. Therefore, the species has met the relevant elements of Criterion 2 to make it eligible for listing as Endangered.

<b>Criterion 3. Population size and decline</b>			
	<b>Critically Endangered Very low</b>	<b>Endangered Low</b>	<b>Vulnerable Limited</b>
Estimated number of mature individuals	<b>&lt; 250</b>	<b>&lt; 2,500</b>	<b>&lt; 10,000</b>
AND either (C1) or (C2) is true			
C1 An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)	<b>Very high rate 25% in 3 years or 1 generation (whichever is longer)</b>	<b>High rate 20% in 5 years or 2 generation (whichever is longer)</b>	<b>Substantial rate 10% in 10 years or 3 generations (whichever is longer)</b>
C2 An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	<b>≤ 50</b>	<b>≤ 250</b>	<b>≤ 1,000</b>
(a) (ii) % of mature individuals in one subpopulation =	<b>90 – 100%</b>	<b>95 – 100%</b>	<b>100%</b>
(b) Extreme fluctuations in the number of mature individuals			

#### **Evidence:**

#### **Eligible under Criterion 3 C1 for listing as Vulnerable.**

The number of mature individuals is not known with certainty (Hines 2012; Quick et al. 2015). However, the Committee considers it limited and likely under 10 000 individuals, given the very low numbers recorded from many well surveyed sites (Goldingay et al. 1999; Hines & the South-east Queensland Threatened Frogs Recovery Team 2002) and species disappearance from some previously known sites (Goldingay et al. 1999; DPIE 2000; Hines & the South-east Queensland Threatened Frogs Recovery Team 2002; Hines 2012; Newell et al. 2013; Newell 2018). A total of just 1722 records of Fleay's Barred Frog are recorded in the Atlas of Living Australia (as of 20 April 2020), with the majority (1217) recorded in the decade 2000-09 (ALA 2020). This meets the threshold for listing as Vulnerable.

Following the recent 2019-20 bushfires, and into the immediate future (within three generations), a substantial population reduction is projected (as identified in Criterion 1). The direct and indirect impacts of the bushfires are the primary factors in this decline, with the surviving population further fragmented and less likely to recover from extreme events, such as climate change and disease (Drielsma & Ferrier 2009; Hagger et al. 2013; Newell et al. 2013). The

Committee projects the extent of the decline to be over 10 percent. Therefore, the species has met the relevant elements of Criterion 3 to make it eligible for listing as Vulnerable.

<b>Criterion 4. Number of mature individuals</b>			
	<b>Critically Endangered Extremely low</b>	<b>Endangered Very Low</b>	<b>Vulnerable Low (Medium-term future)<sup>1</sup></b>
Number of mature individuals	<b>&lt; 50</b>	<b>&lt; 250</b>	<b>&lt; 1,000</b>
D2 <sup>1</sup> Only applies to the Vulnerable category Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time	-	-	<b>D2.</b> Typically: area of occupancy < 20 km <sup>2</sup> or number of locations ≤ 5

<sup>1</sup> The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments that demonstrate eligibility for listing under other criteria may include information relevant to D2. This information will not be considered by the Committee in making its assessment of the species' eligibility for listing under the EPBC Act, but may assist other jurisdictions to adopt the assessment outcome under the [common assessment method](#).

**Evidence:**

**Not eligible.**

The number of mature individuals of this species is not known with certainty. However, the Committee considers it likely over 1000 individuals (see Criterion 3), which is not considered low. Therefore, the species has not met this required element of this criterion.

<b>Criterion 5. Quantitative Analysis</b>			
	<b>Critically Endangered Immediate future</b>	<b>Endangered Near future</b>	<b>Vulnerable Medium-term future</b>
Indicating the probability of extinction in the wild to be:	<b>≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)</b>	<b>≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)</b>	<b>≥ 10% in 100 years</b>

**Evidence:**

**Insufficient data to determine eligibility.**

Population viability analysis has not been undertaken.

**Conservation actions**

**Recovery plan**

The *recovery plan for stream frogs of South-east Queensland 2001-2005* (Hines & the South-east Queensland Threatened Frogs Recovery Team 2002) was developed by the Queensland state government and adopted under the EPBC Act in 2003. It is due to expire in 2022.

The recovery plan includes Fleay's Barred Frog (as one of seven stream-breeding frogs detailed) and has been partially implemented, with some management and research actions undertaken at state level. The Committee recommends that following expiry of the existing

recovery plan, a new national recovery plan for *Mixophyes fleayi* is not required as it would not have a significant conservation benefit above existing mechanisms. An approved conservation advice provides sufficient direction to implement priority actions and mitigate against key threats.

## Primary conservation actions

### 2019-20 bushfire response

- As per the guidance developed by Southwell (2020), conduct on-ground surveys to establish the extent of the population response to the 2019-20 bushfires and to provide a baseline for ongoing monitoring.
- 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 species 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.
- Control weeds and conduct habitat restoration works to support the regeneration of forest and streambank habitat at some localised sites. Note: cutting and pasting/painting methods should be used to control weeds as herbicide formulations can be toxic to frogs and tadpoles, particularly if they contain glyphosate and surfactants (Mann et al. 2003).
- Establish the impact of fire retardants used to fight bushfires on frog populations.

## Conservation and management priorities

### Habitat loss, disturbance and modifications

- Protect unburnt habitat (as per primary conservation actions).
- Minimise human disturbance to Fleay's Barred Frog and its habitat. Designate protection zones around known site locations to ensure habitat is not fragmented by roads, timber harvesting or clearing of freehold land. Activities permitted in protection zones should be dictated by further research into the effects of disturbance on Fleay's Barred Frog.
- Assess the effectiveness of current forestry management practices in ameliorating disturbance to the habitat of Fleay's Barred Frog, and revise management practices if necessary.
- Investigate options for enhancing the resilience of the species' current habitat to climate change and options for providing new habitat that would be suitable for the species under climate change scenarios.
- Identify key sites and implement a program ensuring enough suitable habitat is maintained to ensure the species' viability in the wild.
- Identify and conserve landscape characteristics that facilitate movement between subpopulations.
- Educate landowners and managers of the importance of maintaining riparian habitat and the integration of habitat protection into land management regulations.
- Manage flow regimes to enhance breeding opportunities for Fleay's Barred Frog by liaising with water management authorities in each catchment to ensure that any

potential stream works (e.g. diversions, impoundments) and maintenance works (e.g. de-silting of water storages) do not impinge upon Fleay's Barred Frog habitat, do not degrade water quality, and do not substantially affect current flow regimes.

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

- In areas burnt by the 2019-20 bushfires, control introduced species (predators, herbivores, and weeds) in localised areas to support species recovery and habitat regeneration.
- Develop and implement longer-term strategies to control introduced and native predators (including the Freshwater Yabby) by implementing eradication programs, where feasible.
- Monitor and control damage to riparian areas by feral pigs. This may require a collaborative strategy with land holders and local government authorities to control numbers and potentially fence key sites, where feasible.
- Monitor and control any invasion by the cane toad into stream habitat used by Fleay's Barred Frog by implementing eradication programs, as necessary.
- Use fencing, or other measures where applicable, to reduce the access of domestic stock to stream banks.
- Assess the impact of exotic weeds on habitat suitability for Fleay's Barred Frog. If impact is shown to be significant, develop a strategy for control or elimination of the invasive weeds. Note: cutting and pasting/painting methods should be used to control weeds as herbicide formulations can be toxic to frogs and tadpoles, particularly if they contain glyphosate and surfactants (Mann et al. 2003).

#### Disease

- Investigate measures for minimising the impact of *Bd* on Fleay's Barred Frog subpopulations. In particular:
  - Establish the susceptibility of Fleay's Barred Frog to *Bd* and whether the species has developed an immune response or if the strain is reduced in virulence.
  - Investigate options for *Bd* refuge sites, either within or outside of the natural known range of the species, that may be used if required.
  - Conduct research into mechanisms of frogs' resistance to *Bd*, with any identified mechanisms considered to be used in selective breeding methods to produce resistant frogs for release, if required.
- Minimise the spread of *Bd*.
  - Implement 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 Fleay's Barred Frog and its habitat. These include water resource plans, park management plans, and environmental impact assessments.

- Provide advice to private land holders and community groups on how to protect and restore habitat.
- Engage interested nature conservation, land management, and land holder groups in conservation management activities and citizen science projects, such as non-invasive monitoring through the [FrogID](#) project. Activities need to be carefully managed to prevent disturbance to frogs (particularly in breeding season) and participants 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.

### **Survey and Monitoring priorities**

- Conduct on-ground surveys to establish the extent of the population response to the 2019-20 bushfires and to provide a baseline for ongoing monitoring.
- Undertake monitoring for a small number of subpopulations regularly during spring, summer and autumn. Frogs should be individually marked to provide detailed information on population dynamics and ecology.
- Undertake regular broad scale monitoring 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.

### **Information and research priorities**

- Investigate options for linking, enhancing or establishing additional subpopulations.
- Improve understanding of the extent and impact of *Bd*-infection on Fleay's Barred Frog by building on ongoing research, including an ARC grant program on species recovery from *Bd* infection and an NSW Environmental Trust Grant on *Bd* (both yet to be published, as of June 2020), to better inform how to apply existing or new management actions relevant to the recovery.
- 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.
- Assess the effects of fire on Fleay's Barred Frog survival and reproduction, including:
  - Impact of altered environmental attributes, such as in sediment loads, stream hydrological regimes, riparian vegetation structure and composition, and impacts on introduced predators.
  - The species' long-term response to major fire events or altered fire regimes, through identifying those parts of its range that are most vulnerable, or conversely, where there are opportunities for enhancing refuges from fire.

### **Captive breeding/re-establish populations**

- Investigate options for reintroductions if subpopulations continue to become fragmented and isolated, especially if declines continue within isolated subpopulations. Any assisted translocation program should be done via captive reared and released animals. Where not deemed a threat to survival, monitor the movements of individuals via mark-recapture methods, radio tracking or genetic methods.

## **Recommendations**

- (i) The Committee recommends that *Mixophyes fleayi* be retained in its current listing status of Endangered in the list referred to in section 178 of the EPBC Act as there is insufficient evidence to support transferring it to a different category and inclusion of the species in that category is having a beneficial impact on the continued survival of the species.
- (ii) The Committee recommends that there not be a recovery plan for this species.

Threatened Species Scientific Committee

03/09/2020

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