Australian Government
Department of Agriculture, Water and the Environment

Conservation Advice for *Mixophyes balbus* (Stuttering Frog, Southern Barred Frog in Victoria)

In effect under the *Environment Protection and Biodiversity Conservation Act 1999* from 23 November 2021.

This document provides a foundation for conservation action and further planning.

Mixophyes balbus (Stuttering Frog, Southern Barred Frog in Victoria) © Copyright, Michael Mahony (2020).

Conservation status

Mixophyes balbus (Stuttering Frog, Southern Barred Frog in Victoria) is listed in the Vulnerable category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) effective from 16 July 2000. The species is eligible for listing because prior to the EPBC Act, it was listed as Vulnerable under the *Endangered Species Protection Act 1992* (Cwlth).

The main factors that make the species eligible for listing in the Vulnerable category are substantial decline in numbers and distribution, at least partly attributed to chytridiomycosis.

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

Species information

Taxonomy

Conventionally accepted as *Mixophyes balbus* Straughan (1968).

Donnellan (2008) identified two major clades within the Stuttering Frog, a northern and southern clade, which converge near Barrington Tops, New South Wales (NSW). The divergence between clades is greater than the levels of divergence observed among other *Mixophyes* species, suggesting more than one taxon exists within the Stuttering Frog (Donnellan 2008). Further studies are needed to resolve the status and geographic relationships of these evolutionarily significant units (ESUs). Hunter & Gillespie (2011) recommended northern and southern clades should be given the highest level of conservation priority and managed independently until the taxonomy is resolved. Additionally, further studies are required to identify possible sub-structuring within the northern and southern lineages, particularly south of Sydney, where few extant subpopulations are known and limited genetic material is available.

Description

The Stuttering Frog (*Mixophyes balbus*) is a large, muscular frog, with a snout-to-vent length of 65 mm in the adult male and 80 mm in the adult female. The dorsal surface is yellow-brown to olive-green and diffuses laterally to merge with a yellow-white ventral surface. A dark stripe runs from the snout through the eye to the tympanum. The hind limbs are characterised by several faint, thin dark bars. The fingers are not webbed while the toes are three-quarters webbed. The Stuttering Frog has large, black eyes with vertical pupils, and adults have a pale-blue crescent across the upper half of the eye. This pale-blue crescent, as well as a lack of conspicuous spots or blotches on the side, distinguishes the Stuttering Frog from other *Mixophyes* species. The male advertisement call is a stuttering, soft grating trill of about 10 pulses lasting one to two seconds. This description is drawn from Barker et al. (1995), Cogger (2000), Hunter & Gillespie (2011) and OEH (2018).

The tadpole is large, reaching 65 to 80 mm in length, with a brown-black body and large black spots and flecks on the tail. The body is dorso-ventrally compressed with narrow caudal fins and a muscular tail. The metamorph resembles the adult, but has less distinct dorsal patterns and a rusty red iris. This description is drawn from Barker et al. (1995), Anstis (2002) and OEH (2018).

In captivity, frogs in the southern and northern clades are morphologically distinct (Banks et al. 2014). Frogs in the southern clade have darker eyes, more pointed noses, more bands with more distinct banding on hind limbs and more dorsal markings (Banks et al. 2014). Southern clade females are also smaller and lay more eggs than northern clade females (Banks et al. 2014). However, these differences may not reflect differences between clades in the wild, as only a small number of frogs were collected from single sites (Banks et al. 2014).

Distribution

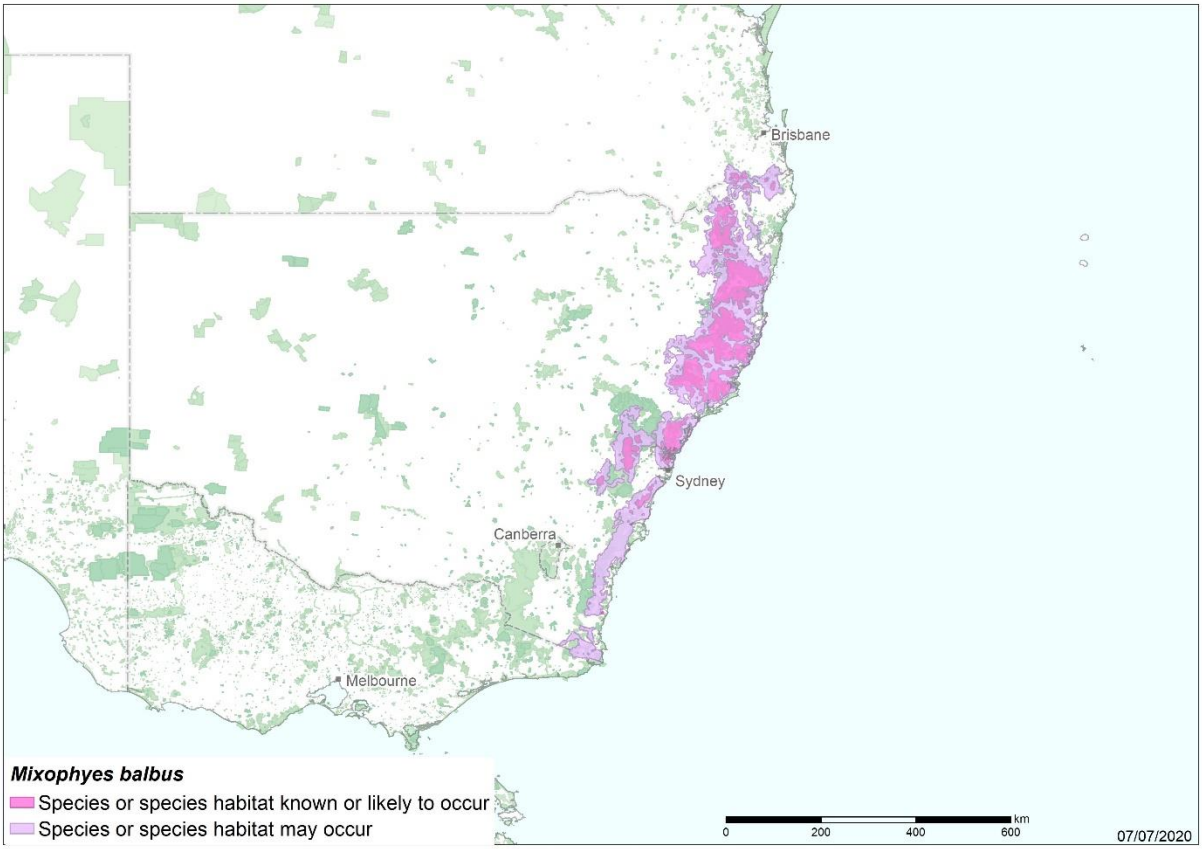
The Stuttering Frog is endemic to the south-east coast of Australia. Historically, it occurred in eastern-flowing streams of the Great Diving Range between the Clarence River catchment in north-eastern NSW and the Cann River catchment in East Gippsland, Victoria (VIC). However, the species has undergone widespread decline across much of this range (Mahony 1993; Tyler 1997), particularly south of Sydney, where it has only been recorded eight times since 2000 and not since 2011 (Daly et al. 2000; White 2000; Hunter 2001; ALA 2020). The Stuttering Frog may be extinct in the wild in Victoria, as it has not been observed since 1983 (Gillespie & Hines 1999) and was not detected in targeted surveys of suitable habitat (Gillespie et al. 2014). A Stuttering Frog call may have been detected incidentally in the Thurra River in East Gippsland in March 2011 (Urlus & Marr 2011), however, this has been described as highly doubtful by Clemann & Gillespie (2012).

The Stuttering Frog persists in the New England Tablelands, NSW North Coast, NSW South Western Slopes, South East Corner, South Eastern Highlands and Sydney Basin IBRA bioregions (OEH 2018). The Dorrigo region in the NSW North Coast bioregion may be a stronghold for this species (OEH 2018). The Stuttering Frog was formerly more frequently encountered in the northern part of its range than south of Sydney, although this may reflect limited historic searches in the region (Gillespie & Hines 1999). The Stuttering Frog occurs from near sea level to 1100 m above sea level (ASL) in the southern part of its range, and from 200 m to 1420 m ASL in the northern part of its range (Gillespie & Hines 1999). It is the only *Mixophyes* species that occurs in south-eastern NSW (OEH 2018).

In 2009, the estimated population size of the Stuttering Frog was fewer than 10 000 mature individuals (Gillespie et al. 2009). Additionally, no subpopulations were estimated to contain more than 1000 mature individuals (Gillespie et al. 2009), as low abundance was recorded for most subpopulations (Mahony et al. 1997). In 2020, the Bushfire Expert Panel indicated that the Stuttering Frog population was increasing prior to the 2019-20 bushfires (DAWE 2020).

A Stuttering Frog subpopulation at Macquarie Pass National Park, south of Sydney, was discovered in 2000, and peaked with 200 to 300 tadpoles in January 2005, and then declined to 15 tadpoles in September 2005, most likely due to the amphibian chytrid fungus, *Bactrachochytrium dendrobatidis (Bd)* (Daly & Craven 2011). The subpopulation is now considered extinct, but a captive subpopulation was established using tadpoles from this subpopulation (Daly & Craven 2011) and there are plans to re-release individuals in this area (Daly 2017).

Map 1 Modelled distribution of the Stuttering Frog



Source: Species distribution data Species of National Environmental Significance database, base map Geoscience Australia
Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything containing herein.
Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the specific habitat type or geographic feature that represents to recent observed locations of the species (known to occur) or preferred habitat occurring in close proximity to these locations (likely to occur); and (b) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observations records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

The cultural significance of the Stuttering Frog is not known. However, frogs feature in Dreaming Stories across Australia – a well-known example is Tiddalik the Frog (Morton 2006). Frogs were also a likely food source for Indigenous Peoples and incorporated into the social and ceremonial fabric of local Indigenous culture and tradition. Indeed, small creeks, in which the Stuttering Frog occurs, were key elements of pre-colonial relationships between Indigenous Peoples and country (Macdonald 2017). The Stuttering Frog may occur across lands traditionally owned by Bundjalung, Ngarabal, Gumbainggir, Nganyaywana, Biripi, Worimi, Geawegal, Wonnarua, Awabakal, Kuring-gai, Eora, Darkinung, Dharug, Tharawal, Yuin and Bidwell language groups (Map 1 and 2).

Relevant biology and ecology

Habitat preferences

The Stuttering Frog is associated with flowing creeks and streams in temperate and sub-tropical rainforest, wet sclerophyll forest and Antarctic Beech forests (Gillespie 1997; White 2000). It has also been recorded in dry open tableland riparian vegetation (Mahony et al. 1997) and moist gullies in dry forests (Tyler 1997; Gillespie & Hines 1999). In north-eastern NSW, the Stuttering Frog has been found along small first-order tributaries and larger third or fourth-order streams. In south-eastern NSW, the Stuttering Frog has mostly been found in headwaters, along small first or second-order streams (Gillespie 1997). Streams typically have steep banks with deep leaf litter and/or dense riparian vegetation cover (Mahony et al. 1997). No specific geological associations are apparent, as the Stuttering Frog occurs on sedimentary, igneous and metamorphic substrata (Mahony 1999). However, soils are usually rich organic with high humus content (Mahony 1999).

The Stuttering Frog may prefer the interior of large tracts of forest, in areas with relatively cool mean annual temperatures (Gillespie & Hines 1999). Such sites are minimally disturbed by land clearance, forest grazing or other anthropogenic influences, suggesting the Stuttering Frog is sensitive to disturbance (Mahony et al. 1997; Gillespie & Hines 1999). Adults are terrestrial and highly cryptic (Mahony 1993). They shelter in leaf litter or loose soil along the banks and lower slopes of streams during drier periods, but move about above ground at night after heavy rainfall (Mahony 1993).

Reproduction and lifecycle

The Stuttering Frog is an obligate stream breeder and breeds during the spring and summer months, from October to February, usually after heavy rain (Gillespie 1997). Females lay an average of approximately 450 pigmented eggs (2.8 mm diameter) in several nests (Watson & Martin 1973; Lewis 2000; Knowles et al. 2015) and can lay over 1000 eggs in a breeding season (Anstis 2002; Anstis 2013). Eggs are deposited in very shallow, slow-flowing riffle sections of the main channel of streams, in shallow nests dug into gravel or leaf litter substrates or pasted directly onto bedrock (Knowles et al. 1998; Lewis 2000; Knowles et al. 2015).

Upon hatching, Stuttering Frog tadpoles remain in the nest until their yolk sack is fully absorbed and they have attained full motility, after which they disperse into stream channels and pools (Daly 1998). Stuttering Frog tadpoles are free-swimming benthic grazers, foraging amongst stones and leaf litter in riffle and pool sections of the stream channel (Anstis 2002; Anstis 2013; Knowles et al. 2015). Tadpoles can likely survive in streams subjected to brief periods of raised suspended sediments following soil erosion from storms or forestry practices (Green et al. 2004).

Tadpoles can reach metamorphosis in 12–15 months (Daly 1998; Anstis 2002; Anstis 2013), however, this can take up to five years in captivity (Banks et al. 2014). Records on the longevity of the Stuttering Frog are sparse. However, the National Recovery Plan reported a maximum age of six years, with an annual survivorship rate of 60 percent for one subpopulation (Hunter & Gillespie 2011). Accordingly, the generation length of the Stuttering Frog is estimated to be four to five years. This is consistent with the generation length of *Mixophyes fleayi* (Fleay's Barred Frog), an ecologically similar species. Morrison et al. (2004) surveyed Fleay's Barred Frogs in south-eastern Queensland and found males ranged from two to six years and females ranged from three to eight years, with most frogs aged four years. Additionally, Fleay's Barred Frogs were recaptured throughout a six-year capture-mark-recapture study (Newell et al. 2013).

Movement patterns

There are no detailed studies on movement patterns of adult Stuttering Frogs. However, as with the ecologically-similar Fleay's Barred Frog (Doak 2005), the Stuttering Frog may use habitats considerable distances away from riparian areas and may routinely disperse into surrounding forests outside of the breeding season (Mahony 1999). During rainfall events, the Stuttering Frog has been found on roads at least 100 metres from the nearest waterbody, suggesting that individuals move such distances under moist conditions (Mahony 1993; Lemckert & Morse 1999). Accordingly, terrestrial habitats, throughout catchments containing subpopulations of the Stuttering Frog, may be of importance for foraging, shelter and possibly dispersal.

Diet

The diet of adult Stuttering Frogs predominately consists of insects and smaller frogs (OEH 2018).

Habitat critical to the survival

It is not practicable to describe habitat critical to the survival of this species. Large areas of potential habitat for this species are unsurveyed and confirmation as habitat can only be achieved through detection-based presence/absence field surveys. In the absence of confirmed occupancy, potential habitat can be identified as necessary to support the recovery of this species through verification of the presence of habitat attributes. The species eligibility for listing and key threat being the loss, degradation and fragmentation of habitat suggests that all habitat for the species either now or at some point in the near future is likely to be critical to the survival of the species.

No Critical Habitat as defined under section 207A of the EPBC Act has been identified or included in the Register of Critical Habitat.

Important populations

In this section, the word population is used to refer to subpopulation, in keeping with the terminology used in the EPBC Act and state/territory environmental legislation.

At this point in time there is insufficient information available to be able to describe, with spatial information, important populations of this species. Further research is needed to do this, if practicable to do so (see conservation actions). Until such information is available, all populations of this species should be considered important.

Threats

The Stuttering Frog is threatened by habitat loss and fragmentation, climate change, disease and invasive species (Table 1).

Table 1 Threats impacting Stuttering Frog

Threat	Status and severity [a]	Evidence
Climate change		
Increased temperatures and change to precipitation patterns	• Timing: current • Confidence: known • Consequence: major • Trend: increasing • Extent: across the entire range	Climate change is expected to increase the extinction risk of anuran species over the coming century (Hagger et al. 2013; Pearson et al. 2014) and the population size of stream-dwelling frogs is predicted to decrease with increasing severity of climate change (Tanner-McAllister et al. 2018). The CSIRO & Bureau of Meteorology (2015) predict eastern Australia will experience decreased rainfall, increased frequency of droughts and average temperatures. Such conditions could severely impact the duration and seasonality of stream breeding sites, as well as the composition of non-breeding habitat, thereby lowering frog recruitment (Lemckert & Penman 2012). During drought conditions, smaller streams typically used by the Stuttering Frog for breeding are no longer suitable, due to reduced flow (Mahony 1993). Additionally, decreased rainfall will likely decrease mobility above ground, reducing dispersal among subpopulations (Mahony 1993; Lemckert & Morse 1999).

Threat	Status and severity [a]	Evidence
Inappropriate fire regimes	• Timing: current • Confidence: known • Consequence: major • Trend: increasing • Extent: across the entire range	The CSIRO & Bureau of Meteorology (2015) predict eastern Australia will experience decreased rainfall, increased frequency of droughts and average temperatures, leading to bushfires of increased frequency, severity and scale. Accordingly, catastrophic bushfires are increasingly likely to occur due to climate change. Bushfires are predicted to contribute to declines in stream-dwelling frogs in eastern Australia (Tanner-McAllister et al. 2018). Localised extinction of frogs has been observed through bushfire events. Many frog species have little defence against fire, as they are slow, unable to flee and have a low tolerance of extreme temperatures and desiccation (Gillespie et al. 2016). Penman et al. (2006) observed that temperate Australian frog species generally have a critical thermal limit of 34–38 ºC. Bushfires can degrade stream habitats associated with the Stuttering Frog, by increasing water temperature, altering water chemistry and creating sediment/ash runoff 'slugs', which can impact aquatic ecosystems up to 80 km downstream of burnt areas (Lyon & O'Connor 2008; Alexandra & Finlayson 2020). Such 'slugs' can fill in crevices in streams reducing the availability of suitable oviposition sites and refugia for tadpoles (Welsh & Ollivier 1998; Gillespie & Hines 1999) and promoting toxic algal blooms that can deoxygenate water and cause egg and tadpole death (Alexandra & Finlayson 2020). Additionally, bushfires may exacerbate predation risk, as the abundance and activity of terrestrial introduced predators is known to increase following fires (Leahy et al. 2016; Hradsky et al. 2017). In 2019-20, following years of drought (DPI 2020), catastrophic bushfire conditions resulted in extensive bushfires covering an unusually large area of eastern Australia. These bushfires overlapped with approximately 56 percent of the Stuttering Frog's distribution (Legge et al. 2021). Fire severity varied across the bushfire extent, with about 19% of the range burning at extreme severity while 37% burnt at lower severity, possibly with small unburnt patches within that fire footprint (Legge et al. 2021). The Stuttering Frog has been identified as vulnerable to mortality during and after the 2019-20 bushfires, reflecting their distribution in wet eucalyptus forest and rainforest, habitat specialisation and pyrophobic response to fire (DAWE 2020).

Threat	Status and severity [a]	Evidence
Habitat loss, disturbance and modifications		
Vegetation clearing/habitat fragmentation	• Timing: current • Confidence: known • Consequence: major • Trend: static/increasing • Extent: across the entire range	Since European occupation, there has been substantial habitat loss and modification within the historic range of the Stuttering Frog, likely contributing to its broad-scale decline. The Stuttering Frog usually occurs at sites that are minimally disturbed by land clearance, forest grazing or other anthropogenic influences, suggesting that it is sensitive to disturbance (Mahony et al. 1997; Gillespie & Hines 1999). Forest habitat throughout the catchment is important for foraging, shelter and maintaining dispersal levels in the Stuttering Frog (Hunter & Gillespie 2011). However, many remaining Stuttering Frog subpopulations occur in catchments with forestry activities, which can cause mortality of individual frogs, loss of suitable habitat required for movement or dispersal, removal of native vegetation and increased sediment load. Increased sediment load can fill in crevices in stream substrates, reducing the availability of suitable oviposition sites or refugia for tadpoles (Welsh & Ollivier 1998; Gillespie & Hines 1999). However, Stuttering Frog tadpoles can likely survive in streams subjected to brief periods of raised suspended sediments following soil erosion from storms or forestry practices (Green et al. 2004). Additionally, habitat fragmentation, due to urban development and agricultural land use, can isolate subpopulations and increase their vulnerability to local extinction via stochastic events, such as drought or epidemic disease (OEH 2019).

Threat	Status and severity [a]	Evidence
Disease		
Chytridiomycosis caused by the amphibian chytrid fungus *Batrachochytrium dendrobatidis (Bd)*	• Timing: current • Confidence: known • Consequence: moderate • Trend: decreasing • Extent: across the entire range	Chytridiomycosis, is a skin disease of anuran amphibians, caused by *Bd*, which has been implicated in the decline of many frog species in Australia and throughout the world (Berger et al. 1998; Scheele et al. 2019). It is listed as a Key Threatening Process under the EPBC Act (DOEE 2016). Mortality associated with *Bd* erodes the capacity of subpopulations to sustain loss of recruitment associated with drought and reduces resilience to climate change (Scheele et al. 2016). *Bd* has been reported in the Stuttering Frog and related species, including Fleay's Barred Frog, *Mixophyes iteratus* (Giant Barred Frog) and *Mixophyes fasciolatus* (Great Barred Frog) (Berger et al. 1999; Berger et al. 2004; Murray et al. 2010). Chytridiomycosis was the likely cause of local extinction of a Stuttering Frog subpopulation at Macquarie Pass National Park, south of Sydney in 2005 (Daly & Craven 2011). Eradicating *Bd* has never been achieved in wild populations. Some amphibian species are reasonably tolerant, acting as a natural reservoir, spreading the pathogen (Brannelly et al. 2018b). There is no evidence that *Bd* has disappeared from any location in eastern Australia (Voyles et al. 2009; Newell et al. 2013). However, several *Litoria* and *Mixophyes* species, which suffered declines due to *Bd*, have shown signs of stabilisation and recovery without any management intervention since the mid-1990s (Newell et al. 2013; McKnight et al. 2017; Scheele et al. 2017), suggesting the Stuttering Frog population could recover. There is a proposal to reintroduce Chytrid-free Stuttering Frogs to two sites near Nowra, south of Sydney (Daly 2017).
Invasive species		
Habitat damage by domestic stock	• Timing: current • Confidence: suspected • Consequence: major • Trend: static • Extent: across the entire range	Cattle grazing has been identified as a major threat to a stream-breeding frog, *Litoria pearsoniana* (Cascade Tree Frog), in south-eastern QLD and north-eastern NSW (Parris 2001). Cattle and other domestic stock grazing near stream and riparian habitat may trample Stuttering Frog eggs in shallow riffles, as has been observed for Fleay's Barred Frog eggs (Knowles et al. 2015). Additionally, grazing can increase sediment load, which can fill in crevices in stream substrates, reducing the availability of suitable oviposition sites or refugia for tadpoles (Gillespie & Hines 1999). This has potential to affect the Stuttering Frog, because it is an obligate stream breeder with a long aquatic larval period (Gillespie & Hero 1999).

Threat	Status and severity [a]	Evidence
Habitat damage by feral pigs	• Timing: current • Confidence: suspected • Consequence: moderate • Trend: static • Extent: across the entire range	Feral pigs (*Sus scrofa)* are found in all states and territories of Australia, particularly in association with wetlands and river systems and have been listed as a Key Threatening Process under the EPBC Act (DOEE 2017). By wallowing and rooting, feral pigs modify streamsides and increase erosion (DOEE 2017). Increased sediment load can fill in crevices in stream substrates, reducing the availability of suitable oviposition sites or refugia for tadpoles (Welsh & Ollivier 1998; Gillespie & Hines 1999). This has potential to affect the Stuttering Frog, because it is an obligate stream breeder with a long aquatic larval period (Gillespie & Hero 1999).
Predation by introduced fish, European Red Foxes and feral Cats	• Timing: current • Confidence: suspected • Consequence: moderate • Trend: unknown • Extent: across the entire range	Introduced predatory fishes have been implicated in the decline of several amphibian species throughout the world, primarily due to predation on the egg and tadpole stages (Bradford et al. 1993; Gillespie & Hero 1999; Gillespie 2001; Vredenburg 2004). Introduced fish may also act as vectors for pathogens (Kiesecker et al. 2001). The extent to which introduced predatory fishes, such as Brown Trout (*Salmo trutta*) and Plague Minnow (*Gambusia holbrookii*), prey on the Stuttering Frog is unknown. Introduced species have potential to impact the Stuttering Frog, because it is an obligate stream breeder with a long aquatic larval period (Gillespie & Hero 1999). Brown Trout prey on frogs in eastern Australia (Gillespie 2001) and have been released in streams that currently or historically support Stuttering Frog subpopulations. There have been no direct observations of introduced trout impacting the Stuttering Frog (Clulow et al. 2009). However, such observations are difficult to detect without monitoring (Gillespie & Hero 1999; Gillespie 2001). The extent to which terrestrial introduced predators, such as the European Red Fox (*Vulpes vulpes*) and feral Cats (*Felis catus*), prey on the Stuttering Frog is unknown. However, these predators prey on large terrestrial frogs in south-eastern Australia (Gillespie & Hines 1999). Indeed, predation may increase following the 2019-20 bushfires as the abundance and activity of terrestrial introduced predators increases following fires (Leahy et al. 2016; Hradsky et al. 2017).

Threat	Status and severity [a]	Evidence
Habitat competition with Cane Toads	• Timing: future • Confidence: suspected • Consequence: moderate • Trend: unknown • Extent: across part of its range	Cane Toads (*Rhinella marina*) have been recorded at high altitude in the Border Ranges in northern NSW and could reach areas occupied by the Stuttering Frog (Newell 2011). Cane Toads can tolerate the loss of up to 50 percent of their body water (Australian Museum 2020). Additionally, they can survive in areas where temperatures range from 5 to 40 ºC and rapidly acclimate to various thermal regimes (McCann et al. 2014; Australian Museum 2020). Cane Toads prefer disturbed habitats and travel faster through open, cleared areas (Zug & Zug 1979; Brown et al. 2006; Pearson et al. 2009; González-Bernal et al. 2015). Accordingly, the 2019-20 bushfires may facilitate the dispersal of toads into new areas. There is some debate about the net impact of Cane Toads on native frog populations (Shine 2014). Cane Toads may have a negative effect by predating, poisoning, competing with tadpoles (Shine 2014) and may also act as vectors for introduced parasites and pathogens, including *Bd* (Brannelly et al. 2018a).

Timing—identify the temporal nature of the threat;

Confidence—identify the extent to which we have confidence about the impact of the threat on the species;

Consequence—identify the severity of the threat;

Trend—identify the extent to which it will continue to operate on the species;

Extent—identify its spatial content in terms of the range of the species.

Each threat has been described in Table 1 in terms of the extent that it is operating on the species. The risk matrix (

Table 2) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with experts and using available literature.

Table 2 Stuttering Frog risk matrix

Likelihood	Consequences				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Low risk	Moderate risk	Very high risk **Chytridiomycosis caused by the amphibian chytrid fungus *Bd***	Very high risk **Increased temperatures and change to precipitation patterns** **Inappropriate fire regimes**	Very high risk
Likely	Low risk	Moderate risk	High risk **Habitat damage by feral pigs**	Very high risk **Vegetation clearing/habitat fragmentation** **Habitat damage by domestic stock**	Very high risk
Possible	Low risk	Moderate risk	High risk **Habitat competition with Cane Toads** **Predation by introduced fish, European Red Foxes and feral Cats**	Very high risk	Very high risk
Unlikely	Low risk	Low risk	Moderate risk	High risk	Very high risk
Unknown	Low risk	Low risk	Moderate risk	High risk	Very high risk

Priority actions have then been developed to manage the threat particularly where the risk was deemed to be 'very high' or 'high'.

Conservation and recovery actions

Primary conservation objectives

By 2030, the population of Stuttering Frog will have increased in abundance and viable subpopulations are sustained in disease-free habitats.

Conservation and management priorities

Habitat loss disturbance and modifications

- 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 informed by further research into the effects of disturbance on the Stuttering Frog.
- Identify key sites and implement a program ensuring suitable habitat is maintained.

- Encourage landholders to enter land management agreements, particularly in-perpetuity covenants, that promote the protection and maintenance of critical habitat.
- Investigate options to enhance the resilience of the species' current habitat to climate change and options for identifying new habitat that would be suitable for the species under climate change scenarios.
- Identify and conserve landscape characteristics that facilitate movement between subpopulations.
- Assess the effectiveness of current forestry management practices in ameliorating disturbance to the habitat of the Stuttering Frog, and revise management practices if necessary.

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

- 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).
- Monitor and control damage to riparian areas by feral pigs and domestic stock. This may require a collaborative strategy with land holders and local government authorities to control numbers and potentially fence key sites, where feasible.
- Use fencing, or other measures where applicable, to reduce the access of domestic stock to stream banks.

Fire

- Survey known subpopulations during the 2020-21 and 2021-22 breeding seasons to monitor impacts from the 2019-2020 bushfires.
- In the aftermath of fires, manage unburnt areas within or adjacent to recently burnt areas to reduce risks from future fires, in order to provide refuge sites, as well as managing unburnt areas that are not adjacent to burnt areas.
- Consider the need for immediate and ongoing post-fire predator control within the habitat when fires do occur.
- Establish the impact of fire retardants, used to fight bushfires, on frog populations.

Disease

- Collect and analyse samples from all monitoring programs for the species, to test for the presence of *Bd* and improve understanding of disease spread throughout the species' range.
- Establish the susceptibility of the Stuttering Frog to *Bd*, to determine if the species has developed an immune response.
- Investigate availability of *Bd* refuge sites, either within or outside of the natural known range of the species.
- Minimise the spread of *Bd* by implementing suitable hygiene protocols to protect priority subpopulations (Murray et al. 2011), as described in the threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis (DOEE 2016).

Breeding and other ex situ recovery action

- Support and maintain captive breeding and reintroduction programs for northern and southern clades of the Stuttering Frog.

Stakeholder engagement/community engagement

- Engage and involve Traditional Owners in conservation actions, including the implementation of Indigenous fire management and other survey, monitoring and management actions.
- Liaise with the local community and government agencies to ensure that up-to-date population data and scientific knowledge inform the implementation of conservation actions for this species.
- Contribute to impact assessment and planning processes on measures to protect the Stuttering Frog and its habitat, including water resource plans, park management plans and environmental impact assessments.
- Educate landowners and managers of the importance of maintaining riparian habitat, and the integration of habitat protection into land management regulations.

Survey and monitoring priorities

- Survey known subpopulations during the 2020-21 and 2021-22 breeding seasons to monitor impacts from the 2019-2020 bushfires.
- Intensive monitoring should be undertaken 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.
- 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.

Information and research priorities

- Resolve taxonomic uncertainties between the northern and southern clades of the Stuttering Frog. Determine geographic genetic structure; identify evolutionary significant units and their taxonomic status.
- Investigate options for linking, enhancing or establishing additional subpopulations.
- Improve understanding of the extent and impact of infection by *Bd* on the species to better inform how to apply existing or new management actions relevant to the recovery.
- Understand the potential impacts of climate change on the long-term survival of the species, due to altered temperatures, rainfall patterns, bushfires, environmental stressors and diseases.

- Investigate options for reintroductions or assisted colonisation if subpopulations continue to become fragmented and isolated, especially if recent unexplained declines continue within isolated subpopulations.
- Ascertain cultural significance of the Stuttering Frog to Traditional Owners across its range.

Links to relevant implementation documents

National Recovery Plan for the Stuttering Frog Mixophyes balbus (2011)

NSW Saving Our Species strategy: Stuttering Frog (*Mixophyes balbus*)

Translocation proposal. Re-introduction of the Stuttering Frog *Mixophyes balbus* to Nowra NSW (2017)

Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis (2016)

Threat abatement plan for predation by European red fox (2008)

Threat abatement plan for predation by feral cats (2015)

Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*) (2017)

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