Fire Management Guidelines: Red-crowned Toadlet

(Mark Schuster, Bushfire Technical Officer, Ku-ring-gai Council)

Introduction:

One of the threatened species within Ku-ring-gai LGA is the Red-crowned Toadlet (*Pseudophyrne australis*) listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016*. The **red-crowned toadlet** is a species of Australian ground frog, restricted to the Sydney Basin, New South Wales. It is only found around sandstone escarpment areas around Sydney, from Ourimbah in the north, Nowra to the south and the Blue Mountains areas to the west.

The Red-crowned Toadlet (*RCT*) could be termed a '*flagship*' species for biodiversity in Ku-ring-gai LGA. This small and distinctive frog is only found around temporary creeks and soaks in sandstone habitats in woodland, heathland and dry sclerophyll forest around the Sydney Basin. All available evidence indicates that this species is restricted to the Triassic Hawkesbury and Narrabeen Sandstones of the Sydney Geological Basin.

The habitat may be found in steep escarpment areas and plateaus, as well as low undulating ranges and outcroppings. Ironstone capping is a common feature of many sites where this species has been observed. Favoured microhabitats for shelter sites are under flat sandstone rocks ('bush-rock') either resting on bare rock or damp loamy soils. They have also been found under logs on soil, beneath thick ground litter and in horizontal rock crevices near the ground. Within these geological formations, this species mainly occupies the upper parts of ridges, usually being restricted to within about 100 metres of the ridgetop. Although they also occur on plateaus or more level rock platforms along the ridgetop this area is usually less preferred than the first tallus slope

areas below the upper escarpment or just below benched rock platforms (see Figures 1 and 2 below regarding locations of populations on the upper sandstone slopes of Hawkesbury Sandstone lithology). Red-crowned Toadlets usually live in the vicinity of permanently moist soaks or areas of dense ground vegetation or leaf litter along or near head-water stream beds. They prefer the first or second order ephemeral drainage lines commonly called 'feeder creeks' which drain the ridges, benches, cliffs and tallus slopes. These watercourses are often dry or reduced to ponded areas for much of the year and only sustain flow for short periods. Under natural conditions these feeder creeks have flows of high water quality and low nutrient loads, although nutrient seepage from extensive housing placement on the ridgetops in Ku-ring-gai LGA may have altered this situation, leading to potential local RCT population loss.

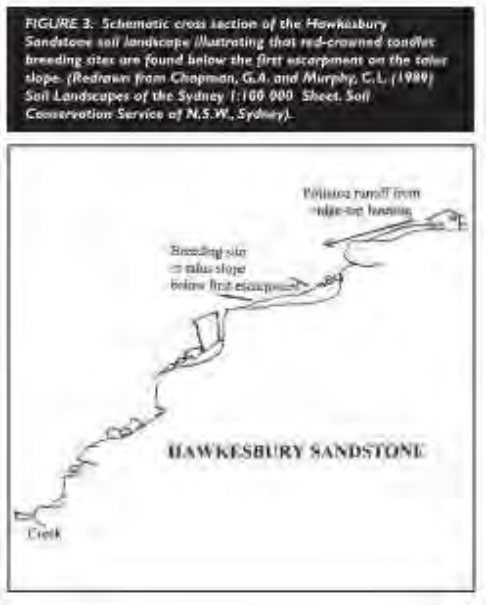

Figure 1. Depicting the topographic location of Red-crowned Toadlet preferred habitat (after Thumm and Mahony, 1999) showing that RCT breeding sttes are found below the first escarpment on the talus slope.

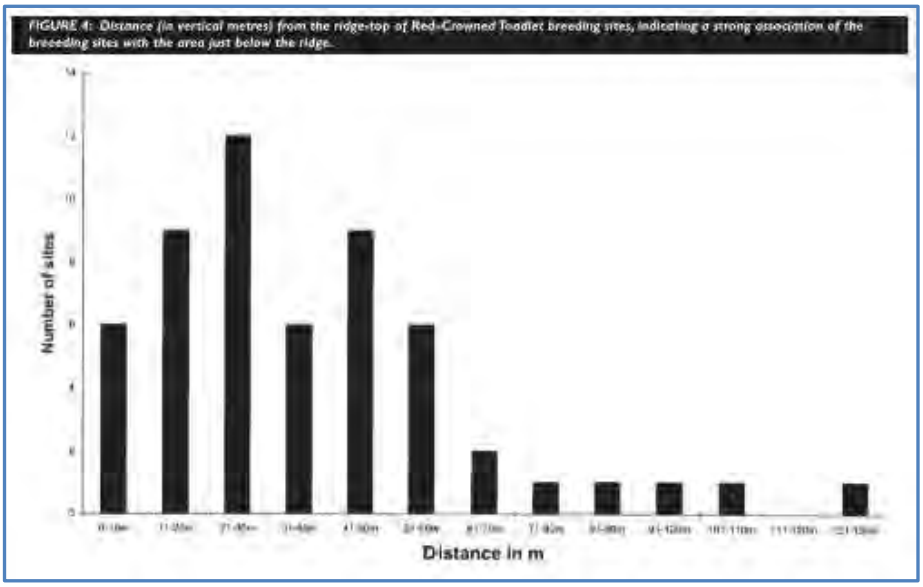

Figure 2. Distance (in vertical metres) from the ridge-top of Red-crowned Toadlet breeding sites, indicating a strong association of the breeding sites with the area just below the top rock shelf, below the ridge-top. After Thumm and Mahony (1999).

The principal vegetation community occupied by this species is Sydney Sandstone Ridgetop Woodland (mainly dominated by *Eucalyptus gummifera* and *Eucalyptus haemastoma*, although a number of different associations within this community are utilised depending upon the area). Other vegetation communities have also been recorded as representing this species' habitat: viz Sydney Sandstone Gully Forest (dominated by *Eucalyptus piperata, Eucalyptus pilularis* and *Angophora costata*, but utilised mainly at the ecotone between this community and the former, rather than in the gullies proper); Coastal Sandstone Heath community (dominated by *Banksia* spp., *Hakea teretifolia*, and *Baekea* spp.), and the Blue Mountains Sandstone Plateau Forest community (dominated by *Eucalyptus sieberi* and *Eucalyptus piperata*). Tree cover when present is usually open and low (10-20m), and the understorey is dominated by a complex range of xeromorphic shrubs.

Males make an "ark" call from nest sites under leaf litter and rocks, in areas likely to be inundated, generally only after heavy rain. Eggs are laid under leaf litter and tadpoles begin developing inside the egg, the males stays with the eggs in the nest. Once heavy rain floods the nest site the eggs hatch and the tadpoles (already fairly developed) finish their development in the temporary pools. In Sydney it is often found in the same habitats as Giant Burrowing Frogs (*Heleioporus australiacus*).

Bushland reserves, with sandstone ridges and lithology within large tracts of intact remnant vegetation and with connectivity to Ku-ring-gai Chase National Park, Garigal National Park and Lane Cove National Park in the north, east and west of the LGA remain a stronghold for populations of RCTs in Ku-ring-gai, with continuing evidence of successful breeding events. Even smaller remnants of bushland, embedded within the suburban 'matrix' can sustain populations of RCT – provided that sandstone shelfs and abundant natural leaf litter is present.

Figure 3. Typical Habitat of the Red-crowned Toadlet, Ku-ring-gai Wildflower Garden

This species has declined due to urbanisation around Sydney, particularly as housing development, particularly in Ku-ring-gai LGA has been concentrated on sandstone shelfs at the tops of ridgelines. However, the species can be still persist in suburbia – if sandstone shelfs and bushland fragments are still preserved in the matrix of development.

As shown in Figure 4 (below) the majority of RCT records are from the sandstone ridgeline habitats along Ku-ring-gai's extensive bushland-urban interface or from the large reserve/national park bushland tracts on the western, northern and eastern sectors of the LGA.

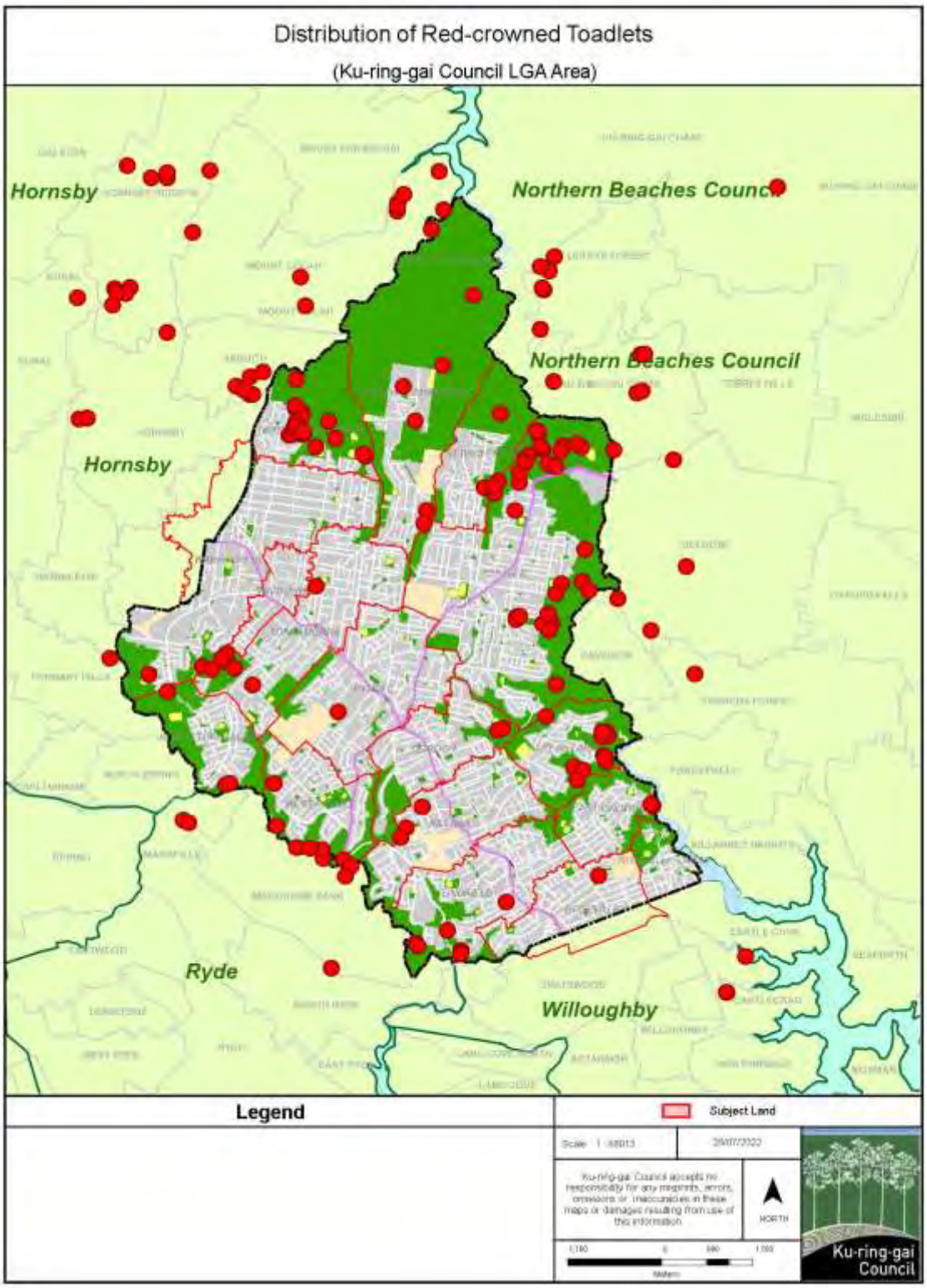

Figure 4. Distribution and known records of the Red-crowned Toadlet (red circles) in Ku-ring-gai LGA (occurrence data from Atlas of Living Australia (28/07/2022 download)

Factors threatening the survival of the RCT include habitat loss and fragmentation leading to isolated sub-populations with little opportunity for dispersal, inappropriate fire regimes that remove nectar-producing understorey plants, the loss of nest sites due to land clearing, and predation by foxes and cats. Fires may include prescribed burns (hazard reduction and ecological burns) or wild fires. Within the LGA, prescribed burns for either ecological or hazard reduction purposes are generally restricted in their frequency (depending on the vegetation type and proximity to residential areas), intensity and size (to ensure fauna connectivity of habitat to unburnt areas), however in some circumstances actions determined necessary to protect life and property are unavoidable (Ku-ring-gai Council, 2020).

Gillespie et. al. (2020) undertook a research study of threatening processes and management actions/research required to assist in long-term conservation of the Australian frog fauna. Although fire management was not directly the primary threat (although it is linked to climate change – a major driver of frog extinction), increased frequency, intensity and extent of fire was identified as a primary threat to 4 species, and a major secondary threat to another 19 species.

Purpose:

With the draft Hornsby Ku-ring-gai Bushfire Risk Management Plan (HKBFRMP) and 5-year program nearing approval, a number of hazard reduction (prescribed) burns are planned by NSW National Parks and Wildlife Service (NPWS), Rural Fire Service (RFS) and Ku-ring-gai Council in the extensive bushland estate along the western (Lane Cove catchment), northern (Cowan Creek catchment) and eastern boundaries (Middle Harbour catchment) of the LGA – which are the primary habitat areas of existing RCT populations.

Typically, these hazard reduction burns are implemented to reduce fuel loads to lower levels and this often ‘targets’ the minimisation/removal of the surface, near-surface and elevated stratum (shrub layer). This is because these layers are often the cause of fire laddering – where a ground-based fire can move into the canopy and also because this layer causes the fire to easily progress across the landscape (horizontal laddering). As RCTs heavily rely on the surface litter for food resources, shelter and breeding, there may be potential impacts on species viability in areas scheduled for hazard reduction activities. Figure 5 illustrates the placement of the 2022-2026 regional burn program along the northern boundary of the LGA. It can be noted that many of these burn blocks overlay primary habitat and population concentrations of the RCT – along the bushland-urban interface zones of the northern and eastern sectors of the LGA.

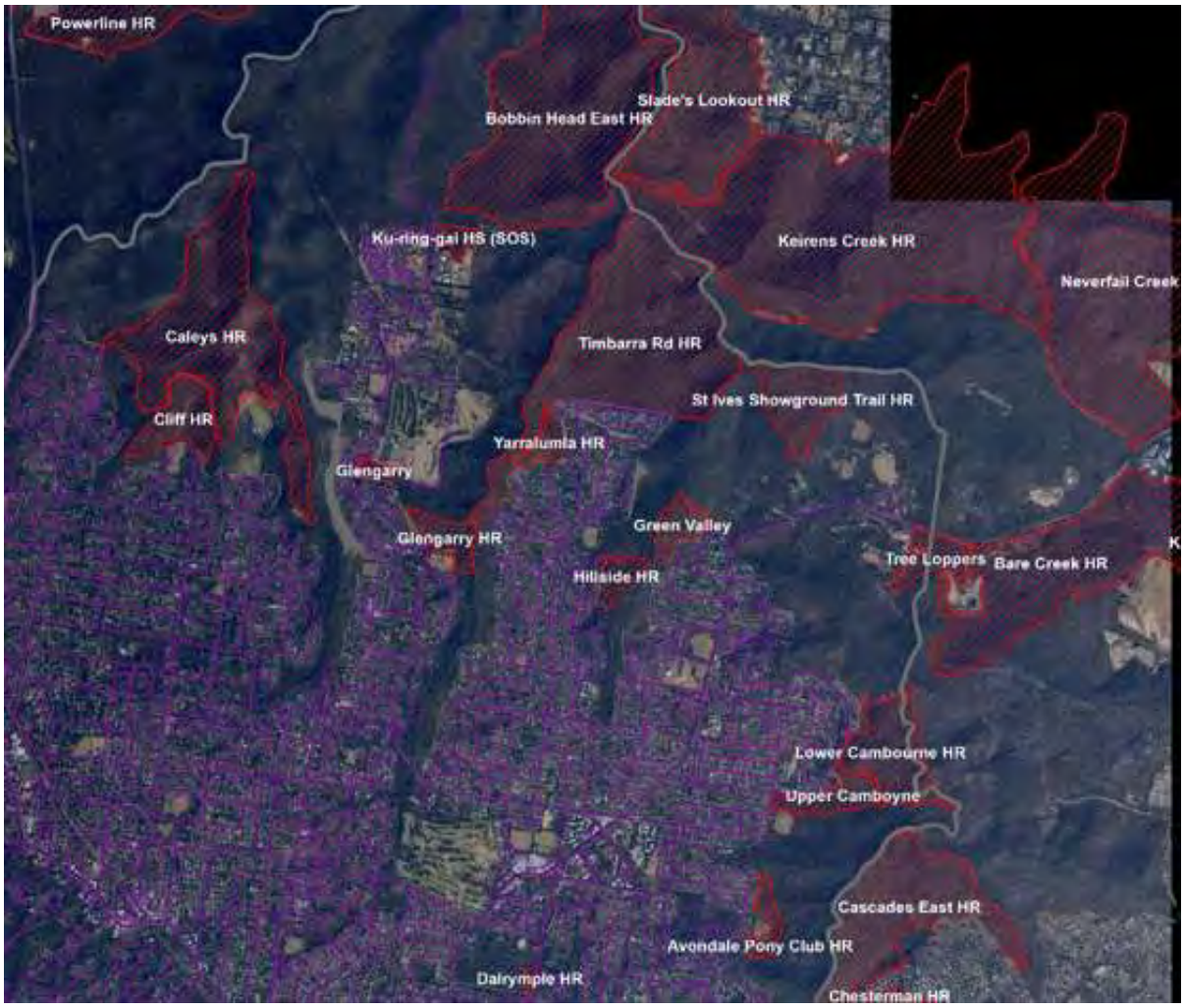

Figure 5. Depicts placement of Hazard Reduction Burns, northern and eastern sectors of Ku-ring-gai LGA – 2021 - 2026

The aim of this guideline is to develop a framework for adaptive fire management actions to ensure for the continuation of both RCT habitat and viable populations. Theses recommended actions can then be incorporated into the burn planning mechanisms prior to undertaking on-ground fire management.

Results - Distribution, Population, Ecology and Fire Impacts

Historically the species has been recorded from the Sydney-Hawkesbury sandstone region that occurs on the periphery of the Cumberland Plain on which Sydney occurs. Urban development extends to these sandstone ridges and plateaus and the entire area has been described as “among the most extensively and irrevocably altered landscapes in Australia”, with around 94 percent of native vegetation cleared (Siversten 1995). Declines have been reported in key populations of the Giant Burrowing Frog throughout NSW and Victoria, especially in areas where habitat fragmentation and loss, caused by forestry, agriculture and increased urbanisation, has occurred (Gillespie & Hines 1999; Mahony 1996). Recsei (1997) also reported that the species has declined throughout many parts of the Sydney-Hawkesbury sandstone region with local declines occurring mostly in areas which have suffered habitat fragmentation, along with direct and indirect impacts from urbanisation, which is placing increasing pressure upon many remaining populations in the region. No recent population surveys of RCT population trends within the Sydney Basin have been undertaken, but it expected, largely due to the pressure of extensive urbanisation and habitat

change, that species populations may have declined – and it may be locally extinct in many developed 'fringe' areas.

The full impact of the 2019-20 bushfires on the Red-crowned Toadlet has yet to be determined but the population is likely to be greatly reduced. The fires may have accelerated any population decline, with much of the frog's distribution in the northern part of its range overlapping with the fire-affected areas, particularly in the Wollemi National Park estate and other sandstone-based bushland landscapes of north and western areas of the Sydney Basin. These fires covered an unusually large area and, in many places, burnt with an unusually high intensity. Its pre-fire imperilment, together with the extent of potential mortality as a result of fire and the unfavourable post-fire conditions (loss of shelter, increased susceptibility to predators, and loss of food), as well as a reduction in future recruitment (egg and tadpole death).

The majority of species records are from the Sydney Basin Bioregion, which was extensively burnt (DPIE 2020). Therefore, the species is assumed to have likely experienced significant impacts from the fires to greater than 50 percent of the population, which will continue to have a detrimental impact over the next one to three generations.

The Red-crowned Toadlets specialised terrestrial reproductive strategy and reliance on ephemeral water flow means that it may be particularly vulnerable to a range of activities that impact on hydrology or water quality. Development adjacent or near Red-crowned Toadlet habitat should assess impacts of runoff, pollution and changes in pH. Redcrowned Toadlets are sensitive to changes in pH outside of the range 5.5 to 6.5. Redcrowned Toadlets have not been recorded breeding in sites that are even mildly polluted nor in permanently flowing watercourses. Most of this species' life is spent under some form of cover, such as rocks, deep leaf-litter, or in rock crevices. It is known that sandstone exfoliations or 'bushrocks' are particularly important to this species, so activities that impact on this microhabitat have the potential to affect this species. Similarly, their utilisation of the ground litter layer may result in them being significantly affected by fire and other activities that cause the destruction of the leaf litter layer. Red-crowned Toadlets are usually found as small colonies scattered along ridges coinciding with the positions of suitable refuges such as drainage lines or other breeding sites. Due to this tendency for discrete populations to concentrate at particular sites, a relatively small localised disturbance may have a significant impact on a population if it occurs on a favoured breeding or refuge site

Figure 1 (p. 4) shows the distribution of the RCT recorded sightings. Many of these recorded location points will be impacted by Hazard Reduction burns during the next 5-year program (2022-2026, as well as large tracts of (unsurveyed) suitable habitat which may contain RCT populations. Due to long-term occurrence of both wildfire and planned burning (for essential hazard reduction activities along the bushland-urban interface), fire management targeted to RCT life history and conservation, needs to be considered in both burn planning and burn operational stages.

A key species group of concern for these systems are frogs of the genus *Pseudophryne*, which make use of pool habitats adjacent to seepages in moist forest habitats. For example, the red-crowned toadlet (*Pseudophryne australis*) is found near permanently moist soaks or along or near head-water streambeds adjacent to first or second order ephemeral drainage lines commonly called 'feeder creeks' which drain the ridges, benches, cliffs and talus slopes (Thumm and Mahony, 1997). These watercourses are often dry or reduced to ponded areas for much of the year and only sustain flow for short periods.

Threatening Processes Schedule 3 of the Threatened Species Conservation Act 1995 lists bushrock removal and high frequency fire as key threatening processes that affect the Red-

crowned Toadlet. The past and continuing illegal collection of exfoliated sandstone rocks from the habitat of this species appears to have had a destructive impact. Habitat that has lost this resource is ecologically disrupted through the reduction of shelter sites and food supply for many species, including the Red-crowned Toadlet. Another factor that appears to significantly impact on this species' habitat is fire. There is a growing body of anecdotal evidence that suggests the intensity and frequency of bushfires plays a significant role in the modification of Red-crowned Toadlet habitat. The observation has been made that Red-crowned Toadlets appear less abundant in habitats affected by wildfire or regularly exposed to hazard-reduction burns.

In Ku-ring-gai LGA, with extensive housing development along the bushland-urban interface (often atop sandstone topography) there is a high potential for 'conflict' between the requirement to protect residents (and property) from bushfire and the need to conserve fire-sensitive flora and fauna. Hazard reduction burning activities are generally carried out in the areas just below the escarpment top – particularly on upper slopes, which is prime breeding habitat of RCTs. Frequent disturbance and degradation of the habitat of this species, clearing (control lines) and actual hazard reduction burning is likely to reduce the size of populations, due to the low recovery potential of this species (Thumm and Mahony, 1999).

Thumm and Mahony (1999) detail the decline of populations due to wildfire. A colony of 15 calling males monitored prior to a wildfire in 1994 was revisited after the fire. Only on male was calling on a day on which there was a lot of activity at a nearby control study site. No leaf litter remained at all in the breeding area at the site of the fire. It was evident that there would be no suitable nest sites available, nowhere to refuge and no foraging areas. No calling was heard at a second site three years after a fire in 1994.

Osborne (1991) stated that fire was a "potential threat" to the corroboree frog (*P. corroboree*), a congenor of the red-crowned toadlet, and suggested that fire may make them more vulnerable to dehydration. It has been observed that red-crowned toadlets retreat to lower clay layers or into the crevices of cliffs in dry times, but that they are found just below the leaf litter in wetter periods. This behavioural trait may assist in their survival – and persistence of viable populations in the upper sandstone shelf habitats – which are prone to extremes of climatic conditions. Whether this attribute assists with their adaptability and survival during periods of fire impact is not known.

Thumm and Mahony (1999) stated that it is not known as to which weather conditions should be chosen for fire hazard reduction burns in order to create the type of fire which would have the least effect on population numbers. This species does not have an "off-season" (i.e. hibernation or aestivation) making forward planning difficult. **Due to their low recovery rate, it is considered that a minimum time span between prescriptions of all fire management activities, within an individual red-crowned toadlet site, of about 10 years (including burning, fire trail maintenance, turbo-mowing and clearing is kept in order to avoid any cumulative impacts from each activities).** However an appropriate scientifically-based fire regime for this species' habitat has yet to be determined.

Daly, Owers and Horton (2015) in their surveys of the RCT in the Nepean-Burragorang National Park estate areas of southwestern Sydney Basin, used the results from their population distribution surveys to exclude the burning of creeklines in the proposed hazard reduction burn blocks that supported the species. The retained leaf litter was a crucial component for the sites where males called and made nests.

Other factors that may threaten populations of the Red-crowned Toadlet include habitat loss and changes to water quality and flow rates. Such impacts may be result from urban development

along sandstone ridges. These impacts may directly threaten Red-crowned Toadlets due to habitat destruction or indirectly, via pollution or siltation of watercourses and alterations to the local hydrological regime. In addition (as shown in the '*case study box*' below, factors such as bituminising road verges can significantly alter their preferred habitat – causing local extinction of RCT populations.

Figure 2. The St Ives road in 2008 and a Red-crowned Toadlet *Pseudophryne australis*. The edges have been sealed and drains put in, destroying the dirt gutters used by populations of Red-crowned Toadlets studied by Moore (1961).

Killara

The main study area of Moore (1961). This seminal work provided information on all of the known frogs from NSW. John Moore used pools in the gutters on the side of "St Ives Road" at Killara as study sites for his observations on the Red-crowned Toadlet. The edge of this road is now sealed (Figure 2b) and these populations were already gone by 1967 (D. Woodruff Pers. Comm.).

Ridge-tops, although less suitable for breeding, may be used as important foraging habitat, so activities that disturb these areas may have consequences for the species in nearby relatively undisturbed habitat

Figure 6 (below) shows the extensive impacts in the Lane Cove catchment resulting from the 1994 bushfires – in terms of both intensity and aerial coverage this bushfire may have destroyed much available RCT habitat – and post-fire recovery (from extant or any adjacent 'unburnt' RCT populations) may have been not possible. In addition, the more recent absence of the ground-dwelling Superb Lyrebird (*Menura novaehollandia*), may add weight to this argument. Possibly the extra pressure from post-burn predation (particularly populations of the Red Fox) may have made post-fire recolonization unviable

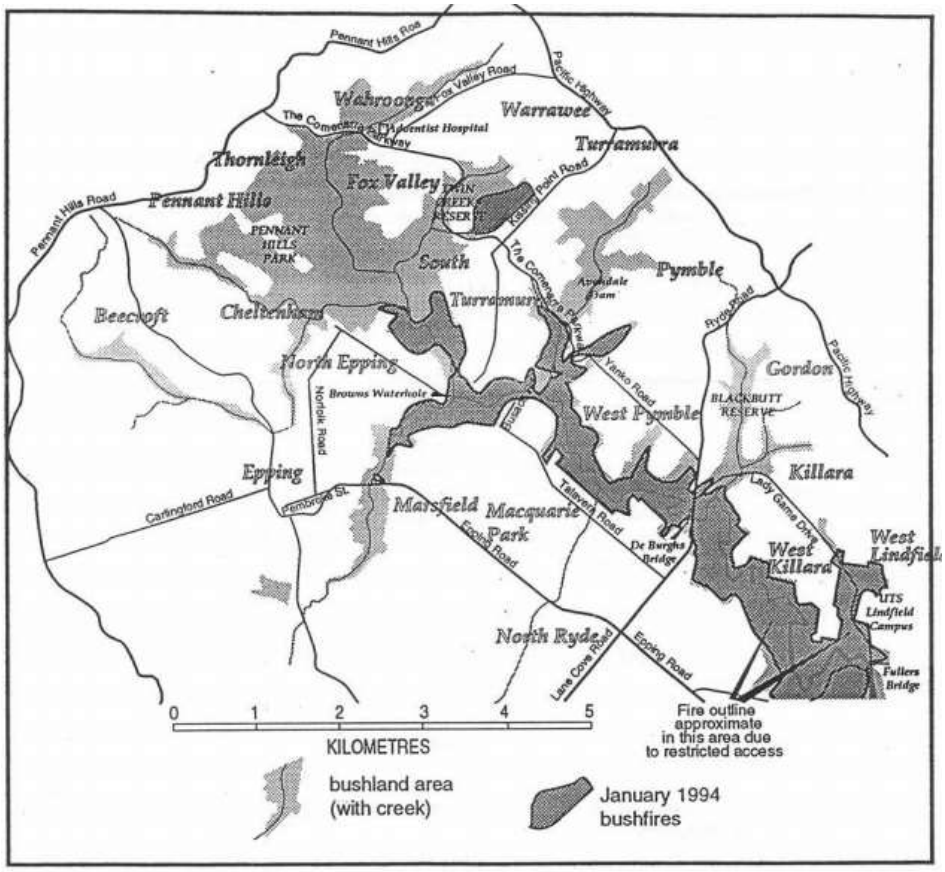

Figure 6. Illustrates fire impacts in Lane Cove catchment from the 1994 bushfires (after Martyn, 1994)

It is apparent that with further long-term monitoring of RCT distributions and fire activity (both planned hazard reduction burns and wildfire events) within the LGA, more definitive conclusions can be made with respect to fire impacts on RCT populations and species viability. Until further data is collected in the forthcoming years, it is critical that the precautionary principle is applied with respect to hazard reduction burning and RCT populations, life cycle needs and habitat suitability.

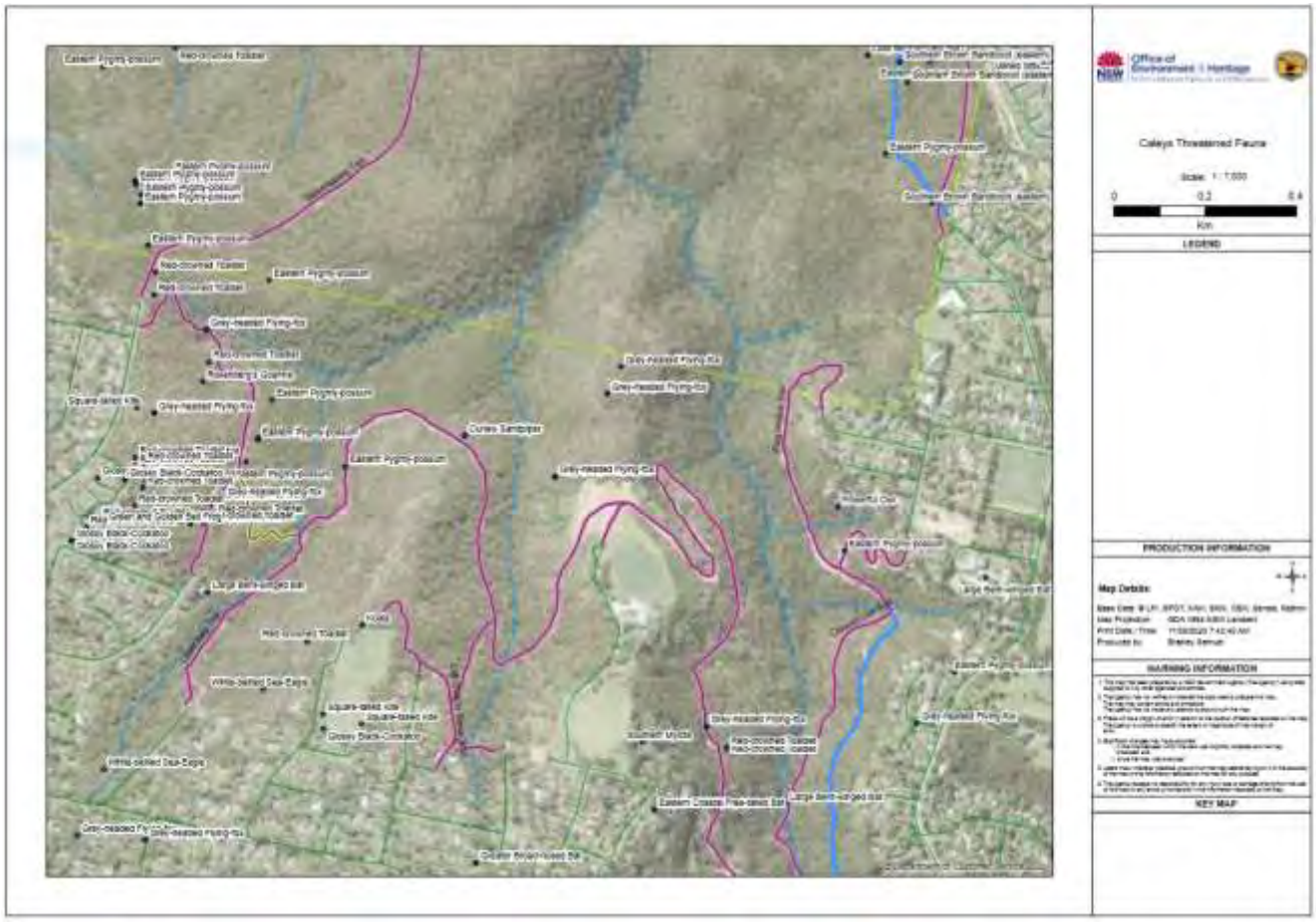

Figure 7. Illustrates point distribution of Threatened and Near Threatened species in an NPWS Burn Plan document (including known RCT records).

When developing pre-requisite burn plans (lodged through the recent RFS GUARDIAN system) the location of RCTs (from known records in State and Federal databases such as BIOBASE) is displayed on mapping, with species-specific conditions listed in the environmental assessment phase of planning. With regard to the RCT in the *Bush Fire Environmental Assessment Code for NSW* (Rural Fire Service, 2021a), the listing has the specific species conditions relating to the use of fire:

"***No burning adjacent to streams, and no burning in and around ephemeral drainage lines at the headwaters of creeks***" and the condition of '***No slashing, trittering or tree removal***' in the instance of usage of mechanical forms of hazard reduction.

The RFS supporting document to the *Bush Fire Environmental Assessment Code*, 'Fire Intervals for Strategic Fire Advantage Zones and Land Management Zones' (see Rural Fire Service, 2021b) gives prescriptive details of the Minimum Fire Interval (i.e. time between consecutive fire impacts) based on ecological thresholds. As all Ku-ring-gai LGA burn blocks are either SFAZ or LMZs, 7 years is the lower interval for 'Sydney Coastal Dry Sclerophyll Forests (i.e. the vegetation type where RCTs habitat occurs).

Further impacts of planned burning may also result in further habitat modification/loss. A typical result with hazard reduction burning is the very frequent loss (often 100% loss even in moderate intensity hazard reduction burning) of the surface (leaf litter) and near-surface vegetation (grasses and small shrubs) layers. This then means that the RCT habitat – shelter, food sources and breeding needs - is fully eliminated for a significant period. Recolonization may only be possible if

the aerial extent of the burn has been limited (allowing for recolonization from unburnt 'edges') or if mosaic (i.e. patch-burning) has been undertaken. This is a critical aspect post-burn or local population extinction can easily occur.

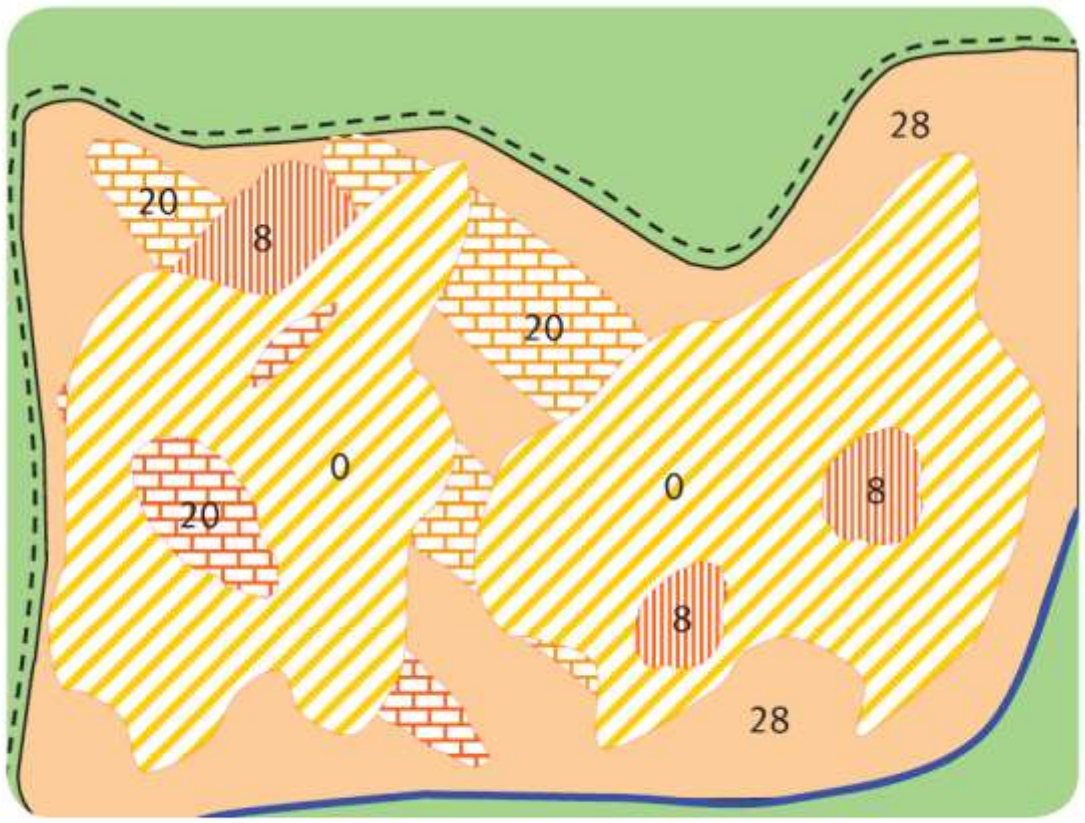

Figure 5: Fire history summary—year 28.
Wildfire and mosaic burn patterns overlaid (with years since last burnt).

Figure 8. Illustrating the principles and spatial/time placement for 'mosaic burning' (from Planned Burn Guidelines, Department of National Parks, Recreation, Sport and Racing (Qld), 2012)

Regarding another threatened species and fire management in Ku-ring-gai LGA, Bob Jones, KMC's Jacob Sife and Inge Buchanan (2015) recommended the following strategies/actions regarding the eastern Pygmy Possum Program and Recovery Plan for Ku-ring-gai Municipality. Input into fire control planning undertaken over the two areas identified and adjacent areas so that:

- **fire intensity is sufficient** to regenerate essential pygmy possum flora such as *Banksia ericifolia*.
- **fire frequency is not too frequent** that it reduces such flora by preventing seeding.
- **fire frequency is not too infrequent** that it reduces such flora by senescence and overgrowth with species that are less suitable for pygmy possums.
- **Fire is excluded at the peak *Banksia ericifolia* flowering time** (late Autumn – Winter), as the species is fully dependant on this plant for its food resources.

The key principles of such strategies/actions may also assist in fire management for the preservation of RCT populations. The key result from these prescriptive management actions is to maintain appropriate habitat for the RCT to maintain viable populations.

Figure 9 (below) these fire regime elements (fire frequency, intensity and extent) into management needs to maintain suitable RCT habitat. As the species is active throughout the year – and breeding can occur throughout a number of seasons, this fire regime element was not considered to be a driver. However, indirect impacts such as invertebrate torpor during winter, mean that any winter burning could impact the food source of surviving toadlets. In addition, mosaic (patch) burning must be incorporated to fully maintain habitat values for RCT local population viability. This is due to the fact that the importance of maintaining at least "clumpings" of intact ground leaf-litter is critical for maintaining RCT populations – at the local scale. Maintaining leaf litter, particularly at the source and 'head' of ephemeral watercourses, should be a paramount concern. Mosaic burning, if undertaken appropriately and with sufficient soil moisture and with the correct prescription, can allow for the persistence of significant areas of leaf litter within a burn block.

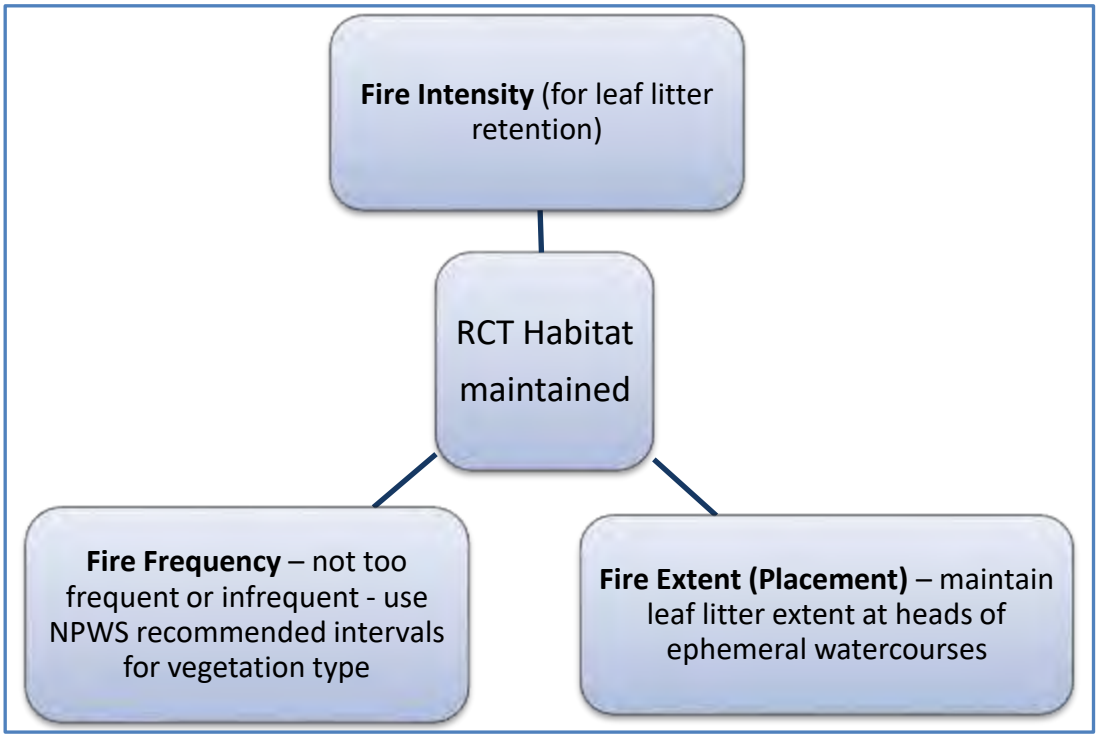

Figure 9. Illustrates the fire regime factors that influence the continuity of RCT habitat and hence species survival.

Only with judicious forward planning and on-ground application of the fire can loss of the surface (leaf litter) layer be avoided, or minimised. A long-term monitoring plan to research fire impacts on RCT populations and habitat, from both planned burns and wildfire, must be undertaken to inform adaptive management for best-practice fire management of our bushland remnants to provide long-term continuity of habitat and species viability.

Recommendations:

Based on previous aspects in this guideline, factors that must be considered when planning and implementing the burn include:

1. ***Burn planning*** phase:
    - Ensure **burn prescription** needs are targeted to achieve **Low-Moderate intensity** fire and burning on high soil moisture (i.e. KBDI = <100; RH = > 30%; Temp = 24 - 28^0C; Maximum Flame Height < 1.5m; Maximum Scorch Height < 6m and ROS <5 metres/minute);
    - Ensure the **Time Since Fire** (TSF) exceeds 10 years for the entirety of the burn block;
    - Ensure prescription specifies **Mosaic** (patch) burn and that **25 – 40% remains unburnt in the burn block – particularly on upper slopes adjacent/below sandstone outcrops – where ephemeral drainage lines are evident**;;
    - Specifically **add ecological criteria** for the Red-crowned Toadlet In the burn plan; Delineate **burn exclusions areas** within the burn plan map (i.e. areas with high concentrations of RCT) – such RCT breeding sites, generally found below the first escarpment on the talus slope;
    - If possible, incorporate **long unburnt areas** (i.e. TSF >25 years) along the northern and eastern bushland-urban interface that have suitable RCT habitat into Council's ecoburn program;
    - **Ensure the burn program considers the spatial arrangement of the burns across the landscape**- to allow adequate space and timing for recolonisation into burnt areas from adjacent unburnt blocks (i.e. spatial and time placement of burn blocks to maximise recolonisation movements – if required);
    - **Coordinate with other fire agencies** (NSW National Parks & Wildlife Service, Rural Fire Service and Fire and Rescue NSW) to ensure that the RCT guidelines can be discussed and incorporated into their burn programs. NSW NPWS manages large areas of RCT habitat in Lane Cove national Park, Ku-ring-gai Chase National Park and Garigal National Park.

2. ***Operational*** (on-ground) phase;
    - Liaise prior to the burn with Bushfire Technical Officer/Bushland Technical Officer to determine habitat areas where the species has been recorded/potential habitat areas and ephemeral drainage lines – for only limited fire incursion during the burn activity
    - Specific **lighting patterns** to achieve mosaic burning (i.e. judicious placement of **spot lights** – depending on terrain/fuel loadings and delineated 'fire exclusion' zones (habitat patches with tops of ephemeral drainage lines);
    - Avoid lighting, or fire progression in potential RCT **breeding sites – generally found below the first escarpment on the talus slope.**
    - Use specific **lighting patterns** (**limited spot lighting**) to achieve low of fire intensity within the burn block – i.e. sufficient fire intensity to ensure fire progression, but also taking care to ensure the ground stratum, including leaf litter is at least partially retained post-fire. **Burning on high soil moisture** will aid in this process;
    - Specific attention to **maintaining patchiness** throughout the burn – i.e. so 25 – 40% of the block remains unburnt

The dilemma of having **sufficient fire intensity** to minimise fuel loads and yet retain a large extent of leaf litter at the heads of ephemeral streams/watercourses is a difficult issue – as a more intense fire can readily destroy 100% of leaf litter. Although each burn must be approached on a case-by-

case basis, having a Low-Moderate fire – with some variation in intensity at spots within the burn block may allow us to achieve both aims – judicious spot lighting at the top of sandstone shelfs will assist in maintaining large areas of leaf litter, which is prime habitat for the RCT. Burning on high soil moisture also will assist in achieving this aim. Further research is urgently required on the topic of fire intensity, the persistence of leaf litter refuges and how much mosaic burning (% unburnt) for RCT life cycle requirements and population persistence.

Long-term monitoring at a number of known RCT sites will be required – to further inform and refine these fire management guidelines for the RCT and its habitat requirements.

References

Daly, G., Owers, B and Horton, A. 2015. *The distribution of the Red-crowned Toadlet Pseudophryne australis in the Nepean-Burragorang region of the Sydney Basin*. Australian Zoologist 37(4): 535-540

Department of National Parks, Recreation, Sport and Racing (Qld). 2012. *Planned Burn Guidelines*: New England Tableland Bioregion of Queensland. Queensland Government, Brisbane.

G.R. Gillespie, J.D. Roberts, D. Hunter, C.J. Hoskin, R.A. Alford, G.W. Heard, H. Hines, F. Lemcke rt, D. Newell, B.C. Scheele. 2020.*Status and priority conservation actions for Australian frog species***.**Biol. Cons., 247 (2020), Article 108543, 10.1016/j.biocon.2020.108543

Harrison, L. 1922**.** *On the breeding habits of some Australian frogs*. *Australian Zoologist* 3: 17-34.

Jones, B., Sife, J., and Buchanan, I. 2015. *Eastern Pygmy Possum Program and Recovery Plan for Ku-ring-gai Municipality (Second Draft).* Internal document, Ku-ring-gai Council, NSW.

Krefft, G. 1863. *On the batrachians occurring in the neighbourhood of Sydney, with remarks upon their geographical distribution*. *Proc. Zool. Soc. London.* 386-390.

Martyn, J. 1994. *Bushfire2: Effects on the Upper Lane Cove Valley*. In STEP Newsletter, No. 65, February 1994 (online).

Moore, J. A. 1961. *The frogs of eastern NSW. Bull. Amer. Mus. Nat. Hist.* 1121: 149-386.

Osborne, W.S. 1991. *The biology and management of the corroboree frog (Pseudophryne corroboree) in NSW*. NSW National Parks and Wildlife Service Species Management Report Number 8. NSW National Parks and Wildlife Service, Sydney.

Rescei J (1997). *The giant burrowing frog Heleioporus australiacus*. In: *Threatened frogs of New South Wales: Habitats, Status and Conservation*. Pp. 56-65.

Rural Fire Service. 2021a. *Bush Fire Environmental Assessment Code*. July 2021. RFS, Sydney.

Rural Fire Service. 2021b. *Bush Fire Environmental Code – Supporting Document: Fire Intervals for Strategic Fire Advantage Zones and Land management Zones*. Sydney, NSW.

Siversten D (1995). *Habitat loss – its nature and effects (including case studies from New South Wales)*. In *Conserving biodiversity: threats and solutions*, pp 29-42.

Stauber, A. (1999). *Geographic variation in Pseudophryne australis: morphological and genetic differences*. B. Sc. Honours Thesis, University of Technology: Sydney.

Stauber, A. (2006) *Habitat requirement and habitat use of the Red-crowned Toadlet Pseudophryne australis and Giant Burrowing Frog Heleioporus australiacus in the Sydney Basin.* PhD Thesis. University of Technology, Sydney, 263 pp.

Thumm, K. and Mahony, M. (1997). *Red-crowned Toadlet. In 'Threatened Frogs of New South Wales: Habitats, Status and Conservation'*. (Ed. H. Ehmann.) pp. 126-36. Frog and Tadpole Study Group of NSW Inc: Sydney.

Thumm, K. and Mahony, M. (1999). *Loss and degradation of red-crowned toadlet habitat in the Sydney region*. In 'Declines and Disappearances of Australian Frogs'. (Ed. A. Campbell.) pp. 99-108. Environment Australia: Canberra.