FROGCALL

THE FROG AND TADPOLE STUDY GROUP NSW Inc.
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NEWSLETTER No. 183 FEBRUARY 2023

Litoria splendida **image by Karen Russell**

You are invited to our FATS meeting. It's free. Everyone is welcome.

Arrive from 6.30 pm or a 7pm start.

Friday 3rd February 2023

FATS meets at the Education Centre, Bicentennial Pk, Sydney Olympic Park

Easy walk from Concord West Railway Station and straight down Victoria Ave. Take a torch in winter.

By car: Enter from Australia Ave at the Bicentennial Park main entrance, turn off to the right and drive through the park. It's a one way road. Turn right into P10f car park.

Or enter from Bennelong Rd/Parkway. It's a short stretch of two way road. Turn left.

Park in P10f car park, the last car park before the Bennelong Rd. exit gate.

FATS MEETING 7PM FRIDAY 3RD FEBRUARY 2023

6.30 pm Lost frogs seeking forever homes: Please bring your membership card (or join FATS on the night) and $50 cash donation. Sorry, we don't have EFTPOS. Your NSW NPWS amphibian licence must be sighted on the night. Adopted frogs can never be released. Contact us before the night and FATS will confirm if any frogs are ready to rehome.

7.00 pm Welcome and announcements.

8.30 pm Main speaker: To be advised.
Arthur White will report on the November 2022 Smiths Lake field trip and discuss ectothermy.
"Why Cold-blooded (ectothermic) animals will outlive us all".

9.30 pm Show us your frog images. Tell us about your frogging trips or experiences. Guessing competition, frog adoptions continue, supper, relax and chat with frog friends and experts.

THE FATS APRIL MEETING
WILL BE HELD ON FRIDAY 31 MARCH 2023

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A BEACON OF HOPE': FROG-SAVING PUSH SPAWNS ZOO'S $500K BREEDING CENTRE

A new frog breeding centre has opened at Melbourne Zoo to house rare species. The three species of frog had much of their habitat destroyed in the Black Summer bushfires. "This facility is like a beacon of hope following the fires and COVID," said Deon Gilbert, a threatened species biologist with Zoos Victoria. Light and temperature controlled rooms, disease control and a food delivery service: welcome to Melbourne Zoo's new centre for breeding critically endangered Victorian frogs.

It's a far cry from the retrofitted shipping containers that were previously used to house this frog recovery program. The new Amphibian Bushfire Recovery Centre, the first of its kind in Australia, has been designed to house three Victorian frog species left on the brink of extinction after the 2019-20 Black Summer bushfires, which destroyed much of their habitats.

A Melbourne Zoo worker shows a southern great burrowing frog at the new centre. *Credit:Luis Ascui*

The spotted tree frog, Watson's tree frog and the southern giant burrowing frog are listed as critically endangered in Victoria. And, like other frogs in Australia, these species are at risk from the deadly chytrid fungus disease, which infects amphibians worldwide. Chytrid fungus causes sporadic deaths in some amphibian populations, and 100 per cent mortality in others. It reached Australia in the 1970s and is more prevalent in cooler and damper areas.

More than 150 southern giant burrowing frogs, reared from tadpoles at the zoo, have already moved into the new facility. These frogs are found in East Gippsland and are one of the rarest and most poorly understood frog species in Australia. The stocky species has powerful muscles in its forearms and hind legs, for burrowing into the earth and crawling across the forest floor, and striking yellow markings on its flanks.

The spotted tree frog, also found in East Gippsland, lives in mountain streams. A smaller species, they are vivid green with bumps all over their skin. The Watson's tree frog has never been kept in a conservation program before, so the zoo hopes to collect tadpoles and breed them next year. "We need to have insurance populations because that gives us a base to get individuals back to the wild," Gilbert said. "That's what we really want to do, not keep them in a zoo forever." The federal government has allocated $200 million to bushfire-affected species, including $1 million to Zoos Victoria that has funded the construction of the Amphibian Bushfire Recovery Centre. The state government said it had spent more than $305 million on Zoos Victoria since 2014.

Since colonisation, Victoria has lost 18 mammal species, two birds, a snake, three freshwater fish, six invertebrates and 51 plant species to extinction. Today, between a quarter and a third of all of Victoria's terrestrial plants, birds, reptiles, amphibians and mammals are considered threatened with extinction, according to the state environment department. This is primarily due to destruction of habitat for housing and agriculture and the invasion of feral species such as cats and foxes. **Forwarded to FrogCall by Brent Morgan. By Miki Perkins 30 September 2022**
https://www.theage.com.au/environment/conservation/a-beacon-of-hope-frog-saving-push-spawns-zoo-s-500k-breeding-centre-20220930-p5bm7m.html?fbclid=IwAR28K0oR00SG7QDRuJYiF-NQHDBdeCp6JH9_b8fArtOKzxjoHp1zHra3lU4

GLIDING TREEFROGS, MINI-MALES AND BURROWING FROGS IN TREES: WHY MELANESIA IS THE WORLD'S TROPICAL ISLAND FROG HOTSPOT

A chocolate treefrog that looks like a Freddo. Burrowing frogs which live in trees. Long-nosed frogs named after Pinocchio. Frogs which go straight from egg to froglet without stopping at tadpole. And large treefrogs which can glide from tree to tree. All these and many more are found only in Melanesia. This tiny region in the South Pacific is a global hotspot of cultural and biological diversity. And we still don't know the full extent of its extreme biological riches.

Centred on the world's largest tropical island, New Guinea, Melanesia is home to 534 types of frog. As our new research shows, that's 7% of all the world's frog species living on just 0.7% of the world's land. And there are more to come. Almost 40% of these frogs have only been scientifically described in the last two decades. Hundreds more species will likely be added to the tally, as we know of at least 190 species not yet formally described. The final tally will be over 700, with frogs colonising every possible niche. But their sheer evolutionary inventiveness also puts them at risk, with many species restricted to tiny ranges.

Winged fingers, erectile noses and tiny males
Melanesia's wealth of frog species easily surpasses other tropical island regions, including famed hotspots such as Madagascar (around 370 species), Borneo and the Caribbean (both around 200). On these islands live more than double Australia's tally of around 248 species. Species diversity goes hand-in-hand with weird and wonderful evolutionary twists. Take the narrow-mouthed frogs, which skip the tadpole stage and hatch directly from egg to frog. In this family, *Microhylidae*, is the likely ancestor of most of the region's frog species after migrating from Asia around 20 million years ago. These frogs were spectacularly successful, calving off an estimated 400 species. Their tally include some of the world's smallest creatures with a backbone, as well as

many burrowing frogs which abandoned the ground to live in trees, and others with complex parental care, such as the father frog guarding his eggs and tadpoles, or carrying babies on his back.

***Litoria pinnochio* just one of over 200 species of Melanesian frog first documented in the last 20 years. Males have an erectile spike at the tip of their snout. Tim Laman**

The treefrogs are numerous too, with an estimated 200 species. Large green treefrog species have evolved finger webbing so they can glide to a lower branch. Other treefrogs have odd nose spikes. And of course, the recently described chocolate treefrog has drawn worldwide attention (and amusement) for its resemblance to a certain confectionery. Other islands have their own unique frogs. On the Papua New Guinean (PNG) island of New Britain lives Boulenger's wrinkled ground frog *Cornufer boulengeri,* a species whose males are 40 times lighter than females. For many years, scientists didn't realise the males and females were the same species.

Why so many frogs? Melanesia's many islands have fertile soil and often have extraordinarily varied landscapes. New Guinea, for instance, goes from sea level to highlands and mountains almost five kilometres high, with a few peaks still holding their last ice. This is a key reason for frog diversity. Why? Because populations can easily become isolated, which speeds up the development of new species. New Guinea, for instance, is one of the world's megadiverse hotspots, containing an estimated 7% of the world's species on a fraction of the land area.

In New Guinea multiple lineage of frogs have independently evolved very tiny size. Pictured is *Choerophryne gracilirostris*, described in 2015. Stephen Richards

We also suspect the arrival of the direct-developing frog family have further supercharged species diversity in Melanesian frogs. These frogs don't have free-living tadpoles able to be dispersed by floods or along streams. This stay-at-home disposition may increase their chances of becoming isolated and evolving into distinct species. Our research found direct-developing frogs in Melanesia have narrower ranges than their more conventional relatives. In fact, the easternmost tip of New Guinea and nearby islands have the most extreme concentration of vertebrates with small ranges anywhere in the world, with more than 160 species jammed into an area less than a quarter of the size of Tasmania.

Melanesia is a good place to be a frog – but threats are arriving The world's frogs are in trouble. Hundreds of species have gone extinct in recent decades. But Melanesia, for now, is a good news story. We know of no frog extinction events and only 6% of species are threatened, compared to a global average of over 30%). This could change if a lethal fungus takes hold. So far, Melanesia has stayed clear of it. Biosecurity measures are essential to conserve this bounty of frogs.

Frogs without a free-living tadpole stage tend to have restricted ranges. Shown here is *Oreophryne oviprotector*, described in 2012. Stephen Richards

Because so many of Melanesia's frogs have tiny ranges, they are particularly vulnerable to changes, such as the loss of a small area of forest. Climate change will pose an existential threat, particularly to frogs dependent on cold climates in the mountains. PNG's eastern biodiversity hotspot around Milne Bay is most at risk. Six species are threatened here by forest loss, while plans for oil palm plantations threaten many frog species. We hope documenting Melanesia's wealth of frogs and other species will help conservation efforts. This region is special. Let's keep it that way. **extracts Forwarded to FATS by Andrew Nelson The Conversation** **https://theconversation.com/gliding-treefrogs-mini-males-and-burrowing-frogs-in-trees-why-melanesia-is-the-worlds-tropical-island-frog-hotspot-192631**

A DEADLY DISEASE HAS DRIVEN 7 AUSTRALIAN FROGS TO EXTINCTION – BUT THIS ENDANGERED FROG IS FIGHTING BACK

Environmental scientists see flora, fauna and phenomena the rest of us rarely do. In this series, we've invited them to share their unique photos from the field. Frogs are among the world's most imperilled animals, and much of the blame lies with a deadly frog disease called the amphibian chytrid fungus. The chytrid fungus has caused populations of over 500 frog species worldwide to plummet, and rendered seven Australian frogs extinct. Our new research, however, has identified an endangered frog species that seems to have developed a natural resistance to the disease, after having previously succumbed to it in prior decades: Fleay's barred frog (*Mixophyes fleayi*).

Fleay's barred frog grows up to 9 centimetres long, and lives near gravelly streams in the rainforests of northern New South Wales and southeast Queensland. It is not the only frog species largely resistant to the disease, with a precious few others also known to survive it, such as common mistfrogs and cascade treefrogs. We speculate that other frog species worldwide may be on a similar trajectory. There is currently no cure for the chytrid fungus, but understanding how Fleay's barred frog and others are fighting back may prove instrumental in helping us bring more species back from the brink.

The killer fungus The amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) causes a skin disease and breached Australian borders in the 1970s. Since then, the disease has caused populations of dozens of species to severely decline, and has driven seven to extinction, including the gastric brooding frogs and southern day frogs.

It wasn't until 1998 that two independent research teams discovered the fungal pathogen was to blame. This unfortunately meant much of the damage was already done prior to its discovery. Similarly, Fleay's barred frog wasn't distinguished as being a separate species of barred frog before the chytrid fungus caused its populations to decline across its range in the 1980s. It became extinct in at least three places it once lived. But our research suggests the Fleay's barred frog is bouncing back. Over four years, we conducted intensive field research at several rainforest streams in northern New South Wales to investigate the prevalence and intensity of infection within Fleay's barred frog populations. We found while some frogs with high-level infections died, most seemed capable of clearing their infections.

Frogs are fighting back Surveys in the late 1990s detected up to 15 Fleay's barred frogs at the sites we studied. But during our investigations, we regularly found close to 100. Moreover, other researchers have noted that these frogs are relatively common across many rainforest streams, suggesting populations of Fleay's barred frog have recovered. We implanted 686 frogs with microchips and tested frogs for the chytrid fungus via a skin swab every time they were captured. This allowed us to follow these frogs over four years to learn about the population's death rates and infection dynamics. Fortunately, male Fleay's barred frogs don't travel far from home and are readily recaptured – we located some frogs more than 20 times. We confirmed the prevalence of the chytrid fungus and the intensity of its infection was influenced by environmental conditions. Specifically, it was greatest with lower temperatures and higher rainfall. This may help explain why we have witnessed mass death events in Australian frogs during recent wet winters along the eastern seaboard.

Fleay's barred frog is also called the silverblue-eyed barred frog. Matthijs Hollanders, Author provided

In addition to investigating the deadliness of a chytrid fungus infection, we also estimated the rates with which individuals were gaining and clearing infections. We found infections were poor predictors of death. Only the highest pathogen loads were associated with an increase in rate of deaths, but frogs were very rarely infected with such high burdens. Instead, frogs were much more likely to clear their infections than to gain them, ultimately leading to a low infection prevalence in the populations. On average, just one in five frogs were likely to be infected at any given time. For those infected, pathogen loads were among the lowest we observed in rainforest frog communities. Some of the other species, such as the cascade treefrog, stony creek frog and giant barred frog, carried loads that were 30% higher.

How this could help save frogs So why can the frogs now deal with a disease that decimated populations just a few decades ago? This question is unfortunately still hard to answer. Given their low pathogen loads and high rates of clearing them, we believe Fleay's barred frogs have developed natural resistance against the chytrid fungus, meaning their immune systems are actively combating infections. We further speculate that other species worldwide may be doing the same. A promising avenue of conservation research is to use the genetic information of some species to help others survive threats in the wild, such as disease or climate change. Fleay's barred frogs may carry just the genes we're looking for.

We now hope to use these resistant frogs for a reintroduction program in nearby Wollumbin (Mount Warning) in NSW, where the species disappeared from in the 1990s. This approach may help the ecosystem of this iconic World Heritage site to thrive. **Forwarded to FATS by Punia Jeffery 4 October 4 2022**
https://theconversation.com/a-deadly-disease-has-driven-7-australian-frogs-to-extinction-but-this-endangered-frog-is-fighting-back-189491

SONGS OF DISAPPEARANCE DEBUTS AT NO. 3 ON THE ARIA CHARTS

Thanks so much to all of you who ordered *Songs of Disappearance* - Australian Frog Calls. On 9 December, our album debuted at No. 3 on the ARIA album charts, behind Paul Kelly and Taylor Swift! It also reached No. 1 on the Australian album chart last week! Not only has the album helped raise national and international awareness on the plight of Australia's frog species, album proceeds also support our national FrogID project.

https://songsofdisappearance.com/?utm_source=wordfly&utm_medium=email&utm_campaign=FrogIDeNewsDec2022&utm_content=version_A&promo=1183

Check out the new *Songs of Disappearance* animation! Artwork by Mervyn Street of Mangkaja Arts and animation by Jodie Austin. **From the FrogID Team calls@frogid.net.au**

https://www.abc.net.au/news/2022-12-10/songs-of-disappearance-frog-sounds-album-makes-aria-charts-debut/101743230

Thanks for sending to FATS Andrew Nelson

Australian Frog Calls: Songs of Disappearance debuted at number three, behind Paul Kelly and Taylor Swift.
Supplied: Jodi Rowley

Striped Marsh Frog *Limnodynastes peronii*
Ashfield NSW image by Monica Wangmann

FROG REPRODUCTION AND COMMUNITY STRUCTURE IN RELATION TO WATER ATTRIBUTES: SETTING THE STAGE TO UNDERSTAND EFFECTS OF CLIMATIC VARIABLES AND CLIMATE CHANGE (extracts)

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Abstract

As amphibians have declined more than other vertebrates and are important environmental bio-indicators for aquatic ecosystems, we must understand how attributes of such ecosystems affect individual frogs, populations, and multi-species communities. For aquatic-breeding frogs, pond physical/ chemical properties influence all life-stages and therefore populations, species, and communities. However, studies have focussed on tadpoles, considered few water variables, and not considered relationships between water attributes and frog populations or communities. Inter-specific differences in how water attributes affect tadpole populations, and hence possibly adult choice of breeding site, should reflect habitats where different species occur, but has been little investigated.

We studied the only frog species on Broughton Island, off the east coast of Australia: the threatened Green and Golden Bell Frog *Litoria aurea* (GGBF); and the widespread and abundant Striped Marsh Frog *Limnodynastes peronii* (SMF). Suitability of pond breeding habitat, measured by encounter rates during 57 visits over 17 years with different life stages, depended on depth, salinity, pH and temperature, with responses by the two species in essentially opposite directions. For both species, encounter rates increased with increasing depth and with decreasing salinity.

Continued from P5 Encounter rates peaked at neutral to alkaline pH for GGBF (i.e., 6.8 to 8.0 or higher) and acidic pH for SMF (i.e., 5.5 to 6.0). As water temperature increased, encounter rates increased for GGBF and decreased for SMF.

Frog community structure depended on average pond temperature and how it changed over time. If recorded temperature, averaged over the year, was less than 22°C or declined to below this level, the GGBF population, as indexed by numbers of adults observed and occurrences of earlier life stages, was low or declined, while the SMF population was high or increased. This threshold yearly average temperature translates into a required temperature at onset of spring breeding for the GGBF of about 20°C. The GGBF population on the island has declined since 1998, when our study began, due to increased aquatic vegetation and consequent decline in water temperature in major breeding ponds. As ponds are small, manual vegetation removal should reverse the trend. A comprehensive understanding of the biological effects of climate change, past and future, can now be pursued.

Introduction **Context and goals** For frogs and other amphibians, it is essential that we understand how attributes of aquatic ecosystems affect the biology of individuals, population dynamics and inter-specific interactions, and the resulting structure of their communities. World-wide, one third of amphibian species have declined over the last 20-30 years leading to many of them being considered ‘threatened’ with extinction or extinct. This high proportion of declining species is greater than for any other animal group (Catenazzi 2015; Stuart *et al.* 2004), and is a worrying sign in that it likely reflects the impacts of habitat loss and pollution on aquatic ecosystems, as amphibians are likely to be especially sensitive to such environmental assaults (Cushman 2006; Stuart *et al.* 2004). Only if we understand how attributes of aquatic ecosystems affect frogs and other amphibians, can we use these animals as environmental bio-indicators for such ecosystems and potentially mitigate adverse anthropogenic impacts on them (Venturino *et al.* 2003).

It is particularly important that we understand the effects of climate change on freshwater aquatic ecosystems, as climate change represents an existential threat to humanity and is caused primarily by human activities (e.g., Intergovernmental Panel on Climate Change 2018), and freshwater ecosystems are significant and important, both to the organisms that occupy them and to human wellbeing (Rockstrom et al. 2014). Climate change has, for example, been implicated as a factor responsible for declines and extinctions in freshwater aquatic-breeding frog species (Laurance 2008; Sodhi et al. 2008). Freshwater ecosystems provide food, drinking water and other human-related benefits (Rockstrom et al. 2014).

To properly comprehend and deal with the impacts of climate change on freshwater ecosystems requires understanding the following three components, as well as links between them: how climatic variables (e.g., air temperature, precipitation, humidity, wind) affect physical and chemical attributes of these ecosystems; how these attributes affect individuals, populations, species, and the associated biological communities; and how the climatic variables have changed, and will likely continue to change in the future. Precipitation, for example, will affect water influx to freshwater ecosystems and hence waterbody attributes such as depth, water temperature, salinity and pH (Chen *et al.* 2019; Krecek *et al.* 2019; Wang *et al.* 2019). This and other associated climatic variables constitute what is generally referred to as the ‘weather’ (Berghuijs and Woods 2016; Ribeiro *et al.* 2016), and are all likely to affect water attributes which are known to influence individual behaviour, growth, development, survival and reproduction for a variety of organisms, including frogs and their larval tadpoles (e.g., Gordon and Tucker 1965; Warner *et al.* 1991), and hence influence populations and species (Alexander *et al.* 2012; Eck *et al.* 2014; Wijethunga *et al.* 2015). How climate change is affecting patterns of air temperature, precipitation, wind and other climatic variables, is becoming increasingly well understood (Intergovernmental Panel on Climate Change 2018).

In other words, these three components are linked together in a logical sequence, with climate change affecting weather patterns, which consequently affect water and other attributes of freshwater ecosystems, which in turn affect the organisms that occupy these ecosystems. It is therefore important to investigate each of these links.

Most GGBF breeding ponds occur in depressions in the rock that are close to the ocean. Depicted is one such pond (i.e., Site 1, Pond 3). The SMF also breeds in such ponds.

However, our understanding remains very limited in terms of how water and other attributes of freshwater ecosystems affect the organisms that occupy them, and how weather patterns influence such attributes. For example, in the case of aquatic-breeding frogs, which we focus on in this article, tadpole growth, development and survival have been found to be affected by a number of water attributes, including depth (Plăiaşu *et al.* 2012), temperature (Eck *et al.* 2014), salinity (Alexander *et al.* 2012), dissolved oxygen (Dmitrieva 2015) and pH (Wijethunga *et al.* 2015), and some studies have considered relationships between frog species community structure and broad-scale factors affecting frog aquatic breeding habitat, such as hydrological regime (Amburgey *et al.* 2014; Hartel *et al.* 2011; Kupferberg *et al.* 2012) and disturbance by livestock (Schmutzer *et al.* 2008). However, the consequences of such influences in terms of climate change have rarely been considered (Eck *et al.* 2014) and no study has investigated the possible effects of water attributes on the population dynamics of adult frogs. Furthermore, the influence of weather patterns on water and other attributes of freshwater ecosystems is not well understood (Krecek *et al.* 2019; Vione and Scozzaro 2019; Wang *et al.* 2019).

We have carried out a long-term study of two species of Australian frog on Broughton Island, which lies about 3 km off the coast of New South Wales, thus providing opportunities to investigate the influence of water and other habitat attributes, that may vary spatially, seasonally and annually, on population and community biology of these frogs. Furthermore, as indicated above, such information can be used to manage populations of these frogs and set the stage for investigations of how climatic variables and climate change affect frogs.

Broughton Island is home to two frog species that differ markedly in distribution, abundance and conservation status. One species, the Green and Golden Bell Frog (GGBF) *Litoria aurea*, is rare and considered threatened with extinction (White and Pyke 2008). The other species, the Striped Marsh Frog (SMF) *Limnodynastes peronii*, is widespread and abundant along the Australian east coast and adjacent ranges (Anstis 2013; Cogger 2000; Ferraro and Burgin 1993; Murphy and Daly 1998).

Our study was initiated with a view to improving management and conservation of the GGBF (White and Pyke 1996; White and Pyke 2008) and has extended over a 17-year period from 1998 to 2014. In 1998, we commenced investigations aimed primarily at understanding the impacts of habitat variables on populations of these two frog species, something that has proven elusive at other locations (Pyke *et al.* 2008; Pyke and White 1996; Pyke *et al.* 2002). Between then and 2014, we surveyed all life-stages of frogs across this island and recorded various physical and chemical attributes within each waterbody. We also observed and recorded changes to the vegetation associated with waterbodies on the island, as apparent relationships between vegetation and water attributes may then indicate appropriate vegetation management for management and conservation of the two frog populations (Pyke 2018; Pyke *et al.* 2008).

Our study also sets the stage for understanding how climate change affects frogs. With information on how climatic variables (e.g., air temperature, precipitation, humidity, and wind) influence the physical and chemical attributes of these waterbodies, combined with links between waterbody attributes and frog population biology, it should be possible to comprehensively understand how climate change affects aquatic-breeding frogs.

Our principal goals were therefore to use our data from this study to:

* Determine relationships between water attributes and frog populations and community structure, across waterbodies and over time, while distinguishing between intrinsic seasonal patterns and other direct influences of water attributes on frogs;

* Evaluate the influence of vegetation associated with the waterbodies on their water attributes, and hence make recommendations in terms of vegetation management aimed at management and conservation of the endangered GGBF;

* Point to future research that should lead to an understanding of how climatic variables and climate change affect frogs.

Results **Seasonal Patterns** Frog breeding behaviour and life stages all exhibited seasonal variation consistent with sinusoidal patterns across months.

For the GGBF, reproduction occurred mostly between December and March with a succession of estimated dates of peak recording rate during this period that corresponded to the natural succession of life stages from calling to metamorphs/ immatures. Occurrences of calling, amplexus and egg laying, which mark the beginning of the breeding season, are estimated to have peaked, on average, in about early December. These behaviours were followed by tadpoles peaking in mid-January and metamorphs / immatures in early March. On average, numbers of observed adults peaked around the end of November, which was just before the peak breeding season.

For the SMF, reproduction was spread over most of the year with no clear succession of breeding behaviours and life stages, and hence no evidence of a seasonal pattern to reproduction. Calling is estimated to have peaked in about mid-February, but strangely amplexus / eggs did not peak until about two months later and tadpoles peaked earlier, in about December or January. Equally strangely, the occurrence of metamorphs / immatures peaked around the end of December and numbers of observed SMF adults peaked around the beginning of March. There is no apparent pattern to these peak occurrences.

Discussion **Changes to Vegetation and Pond Attributes** The ponds in our study changed over time in ways consistent with a general increase in vegetation following cessation of a regime of frequent burning, which occurred shortly before our study began. During our study the extent and height of vegetation have increased, both within ponds and outside of them, especially at sites 1-3. This could have resulted in an increase, on average, in sediment deposited in each pond and hence in a decrease in average maximum depth across all sites. It could also have resulted in increased shading of both ground water flowing into the ponds and standing water in the ponds and hence to lower average water temperatures, especially for sites 1-3. Furthermore, the individual ponds (i.e., Ponds 1/1A; 1/6A; 2/1, 3/Well #1) that exhibited the most noticeable increases in aquatic vegetation generally decreased in average water temperature.

Frog Biology Our results confirm previously known seasonal patterns for breeding by the GGBF and SMF. The GGBF generally breeds predominantly during the warmer months from October to February (Pyke and White 2001), which is consistent with our observations that calling, amplexus and eggs for this species mostly occur during November and December, followed by tadpoles mostly in January. We found that the SMF breeds throughout much or all of the year with no clear
continued on P8

seasonal patterns nor succession of life stage; other authors have suggested similarly (Hengl and Burgin 2002).

Our observed seasonal patterns for water attributes were either expected or unsurprising. Our observed January peak in average water temperature was expected as ponds are all relatively shallow and so pond temperatures should reflect solar radiation and air temperatures, leading to maxima in mid-summer. That average salinities and pH levels exhibited seasonal peaks is also unsurprising as both should be influenced by sea spray, inundation by ocean waves during storms, rainfall and flow of ground water, all of which are likely to vary seasonally. The observed variation in seasonality for salinity and pH among sites and ponds would also be expected as the effects of all of the previously listed factors should vary with pond location.

Effects of Water Attributes We confirmed our expectation that pond suitability for GGBF reproduction should increase with water temperature, at least within the range 10-35°C, though the apparently rapid transition between suitable and unsuitable conditions at around a yearly average of close to 22°C was unanticipated. We found that the likelihoods of recording GGBF adults, calling and tadpoles all increased with increasing water temperature and that ponds changed sharply from being highly suitable for GGBF reproduction to unsuitable as yearly average water temperature was above or below a threshold of about 22°C. Such a yearly average threshold is equivalent to temperatures averaging about 20°C at the beginning of October, when breeding generally commences, about 24°C at the beginning of December, and peaking at about 28°C at the beginning of February.

We also confirmed our expectation that GGBF reproduction would be favoured by low salinity, with a maximum salinity of about 9 ppt. Reproductive behaviour and all life stages for GGBF were recorded less frequently with increasing salinity and were not recorded when recorded salinity was higher than about 9 ppt. GGBF tadpoles were observed only in ponds for which yearly average salinity did not exceed 8.1ppt.

Contrary to expectation, pond suitability for GGBF reproduction was affected by pH, and was greatest under neutral to alkaline conditions (i.e., pH $\geq$ 6.6). For this species, we found that numbers of observed adults and peak recording rates for earlier life stages occurred at pH levels ranging upwards from 6.9 and that tadpoles were observed in ponds that exhibited yearly average pH levels ranging from 6.6 to 8.6 .

Our observations are also consistent with several reports of how pond suitability for GGBF breeding changes as ponds become increasingly shaded or occupied with aquatic vegetation, and colder as a result. At Long Reef Golf Course, within suburban Sydney, artificial ponds into which GGBF tadpoles were introduced were initially suitable for survival of GGBF tadpoles and metamorphs, but subsequently were apparently rejected by adults of this species as breeding sites after they had filled with aquatic vegetation and become colder (i.e., spring average temperature declined from about 21°C to about 17°C and colder) (Pyke *et al.* 2008). At other artificial ponds within the area where the Sydney 2000 Olympics occurred, and which is home to a relatively large population of the GGBF (Bower *et al.* 2014; Darcovich and O'Meara 2008), suitability for GGBF breeding has declined as ponds have become increasingly shaded, or occupied by aquatic vegetation with consequent decrease in the extent of open water (Pyke and White 1999), and conversely has improved after removal of aquatic vegetation or other vegetation causing shade on ponds (Darcovich and O'Meara 2008; O'Meara and Darcovich 2015).

Consistent with expectations, we found that suitability of ponds for breeding by the SMF was affected by water attributes differently and in partly opposite fashion to how these attributes affected suitability for GGBF breeding. As average water temperature decreased, pond suitability decreased for breeding by the GGBF but increased for the SMF. Pond suitability was generally greatest for the GGBF when water was neutral to alkaline and greatest for the SMF under neutral to acidic conditions. Both species apparently required average salinity less than about 9 ppt.

Ponds occur where depressions in overlying organic material intersect the underlying water table. Depicted is one such depression (i.e., Site 3, Swamp 1). The SMF breeds in such depressions, but generally not the GGBF.

Consistent with these differences between the two frog species, the GGBF was favoured by relatively warm water (i.e., avg greater than 22°C) and its abundance was low, or became low, when ponds were cooler than this. For example, as the only or principal breeding ponds for the GGBF became increasingly occupied with aquatic vegetation, and became cooler, the numbers of adult GGBFs observed at these ponds declined dramatically, resulting in SMFs becoming the dominant species at these ponds. On the other hand, ponds that averaged warmer than 22°C, and were neither too saline nor too acidic, remained consistently dominated by GGBFs.

Broad-scale increases in vegetation and associated decreases in average water temperature have resulted in changes in the abundances of the two frog species, with the GGBF increasing and the SMF decreasing. For sites 1-3, where changes to the vegetation have been most apparent and average water temperature has declined over time, abundance of the GGBF has decreased, as indicated by decline in numbers of adult frogs observed and declines in recording rates for calling, amplexus / eggs. For these sites, rates for calling, eggs and

Continued P9

Continued from page 8 tadpoles, have all increased for the SMF, indicating an increase in abundance for this species.

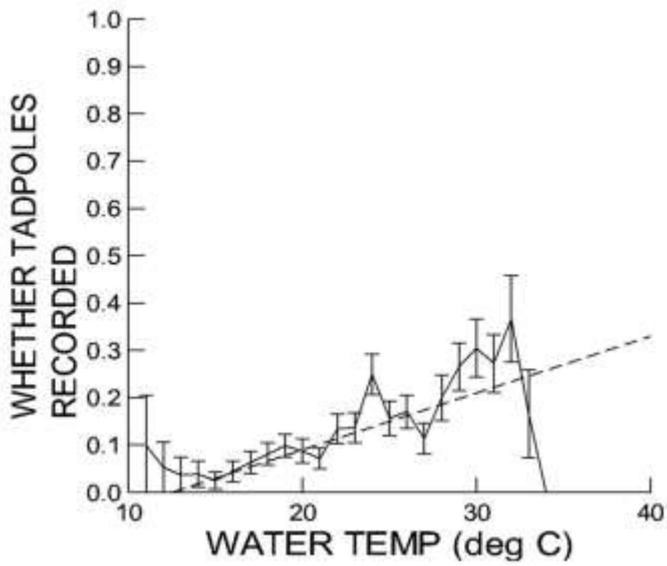
Broad-scale increases in average salinity have resulted in declines in frog abundance, probably for both species. For sites 4-5, where changes to the vegetation have not been noticeable and there have been no significant changes for water temperature and pH, average salinity has increased, presumably as a result of differences in weather patterns between years. The SMF, which has been relatively abundant at these sites, has decreased in abundance, as indicated by decreases in recording rate for tadpoles. The GGBF, which has been relatively rare at these sites, has not exhibited any significant changes in measures of abundance, but is adversely affected by increasing salinity in a similar fashion to the SMF.

Future experimental research Experimental studies could further evaluate our conclusions which have relied on correlational tests of hypotheses rather than experiments. Experimental studies of frog biology have ranged in spatial scale from relatively small containers in laboratory conditions (e.g., Christy and Dickman 2002; van de Mortel and Buttemer 1996) through larger 'mesocosms', some of which have been located outdoors (e.g., Clulow *et al.* 2018), to a few 'field experiments', carried out at relatively large spatial scale (Klop-Toker *et al.* 2017; Melvin and Houlahan 2012; Yamaguchi *et al.* 2016). All such approaches, and combinations thereof, could be applied to our or similar circumstances.

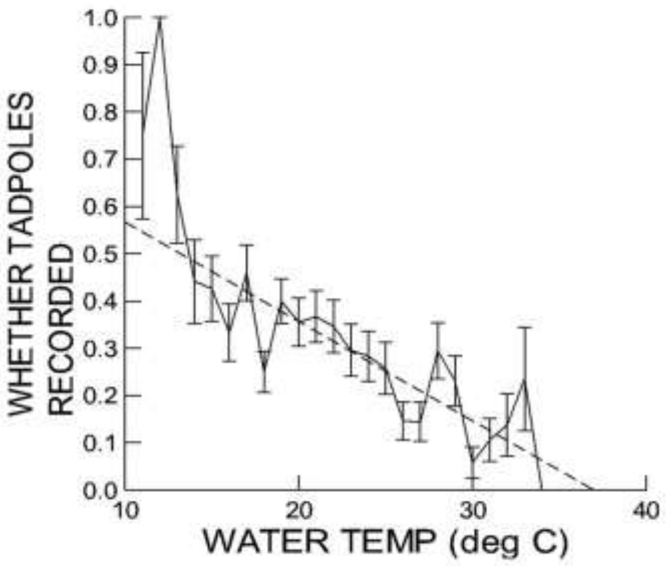
Conservation Conservation and management of the endangered GGBF may depend on water attributes, especially water temperature, as well as other factors such as habitat loss, predation by the introduced *Gambusia*, and chytrid disease. As this species can sometimes flourish in human-created pond breeding habitat (Pyke and White 1996; Pyke and White 2001) and, as indicated by the present study, requires yearly average water temperatures over the year of at least 22°C, artificial habitat for the GGBF can be designed with such water temperatures in mind (Pyke *et al.* 2008). This means, given the seasonal pattern of average water temperature, that water temperatures should ideally be at least 20°C at the beginning of October, which is about when breeding begins, and reach levels of about 28°C or higher by the end of January. It also means that design of GGBF breeding habitat should consider pond dimensions, substrate, and water source, including any connections with ground water, as all are likely to affect average water temperature. In addition, as shading of pond water by aquatic or overhead vegetation can reduce average water temperature, removal of such vegetation may increase the likelihood that water will be sufficiently warm for GGBF reproduction.

At our study location, it should be possible to reverse the decline in GGBF abundance, and hence to improve the conservation prospects for a highly significant population of this species, simply by removing aquatic vegetation from the main breeding ponds for this species. This would not be difficult, given that the ponds on the island are relatively small, but would require approval from various agencies (i.e., NSW National Parks & Wildlife Service, relevant Animal Ethics Committee). Such actions, if implemented, would present a rare opportunity, given information available as a result of the present study, to quantitatively test whether the predicted positive outcomes for the GGBF actually occur.

Climate Change The present study provides a basis for developing a detailed and comprehensive understanding of the biological effects of climate change, past and future, on our two frog species. This can now be achieved by combining studies of how climatic variables (i.e., the weather) affect water attributes in frog breeding habitat, in combination with other habitat factors such as vegetation, how such water attributes affect frog reproduction and population sizes (e.g., present study), and how climatic variables have changed and continue to change as the climate changes. Such a combined approach has not been previously attempted.



Average occurrence of GGBF tadpoles recorded (mean±se) for all sites vs Pond water temperature (°C). Dashed line is least squares linear fit to observations.



Average occurrence of SMF tadpoles recorded (mean±se) for sites 1-3 vs Pond water temperature (°C). Dashed line is least squares linear fit to observations.

Conclusions Our research, which is novel in several respects, points to significant future research. Few studies of frog populations have extended over periods comparable in length to ours (Berven 2009; Ledneva *et al.* 2004; Weitzel and Panik 1993; Welsh and Hodgson 2008). No study has previously linked water attributes with consequences for frog biology across individual reproduction, population sizes and community structure. Furthermore, our study uniquely provides a basis for

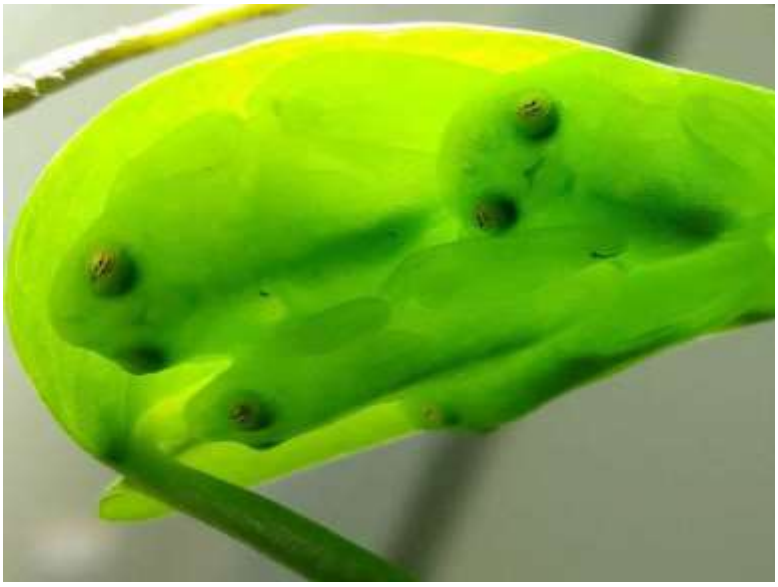
Continued from P9 understanding how climatic variables, and hence climate change, affect frogs. However, experimentation, including through management of frog habitat, may enhance our understanding. It will also be necessary to relate weather events to effects on frog reproduction, something that has not previously been carried out.

Acknowledgments This research has been carried out under a succession of Animal Research Authorities issued by Animal Care and Ethics Committees, based initially at the Australian Museum and subsequently at the University of Technology Sydney (most recently UTS ACEC 2012000259), and under Scientific Licence SL100404 issued by the NSW National Parks & Wildlife Service. These approvals have acknowledged the endangered status of one of the subject species. Additionally, the research has been supported by the Australian Museum, NSW National Parks & Wildlife Service and the University of Technology Sydney. Helpful discussions and comments have been provided by Susanne Callaghan, Hugo Cayuela, Paul Ehrlich, Ross Goldingay, Dan Lunney, Michael Mahony, Evan Pickett, Michelle Stockwell, and an anonymous referee. Many volunteers have assisted, especially through programs based at the Australian Museum and University of Newcastle.

Many thanks to Graham Pyke and Arthur White for permitting FrogCall to copy parts of this article.
https://meridian.allenpress.com/australian-zoologist/article-abstract/42/3/667/472207/Frog-Reproduction-and-Community-Structure-in?redirectedFrom=fulltext
Research article appeared in the Australian Zoologist October 2021 Volume 42 issue 3 Please refer to original article for the full paper, background information, methods, references, data analysis, tables, graphs, images and literature cited. https://doi.org/10.7882/AZ.2021.032

WORLD FROG DAY 20 MARCH

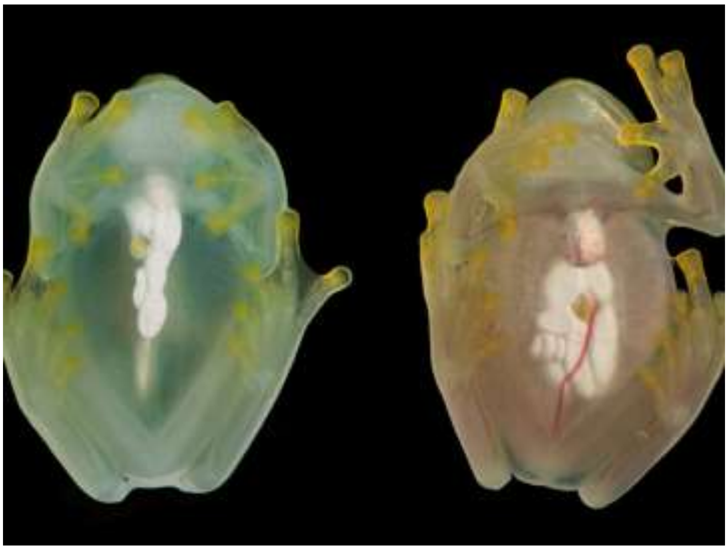
THE ASTONISHING VANISHING ACT OF THE GLASSFROG, REVEALED



A group of glassfrogs sleeping together upside down on a leaf, showing their camouflage.

Jesse Delia says it happened in Panama. A few years back, he was finishing up his field work — a research project examining the parental behaviour of a type of glassfrog. He brought a handful of these transparent, half dollar-sized frogs to the lab for a photo shoot. It led to an exciting discovery. "I wanted to get some photos of a pretty glassfrog belly," Delia tells NPR. He placed them in a Petri dish and saw each frog's circulatory system through its translucent skin — "red with red blood cells." But when he came back later, the frogs were sleeping and the blood "was gone." It was as if the arteries and veins had just melted away. "I thought it was crazy," recalls Delia, now a biologist at the American Museum of Natural History in New York.

He took a video of the glassfrog's pumping heart and sent it to his longtime collaborator, Carlos Taboada, a biologist at Duke University. "It was colorless," Taboada says. Not even the telltale red streak of a vessel in the frog's belly was visible. "It was insane. I had never seen anything like that." Both Delia and Taboada wanted to know — where'd all the frogs' red blood go?



The same glassfrog photographed during sleep (left) and while active (right), showing the difference in red blood cell circulation.

In a new paper in the journal *Science*, Taboada, Delia and their collaborators offer an answer: "They hide most of their red blood cells in their liver," Delia explains. During the day, while the glassfrogs are asleep on green leaves, they're vulnerable to predators, so they achieve camouflage by becoming super transparent. Their livers, among other organs, are coated in highly reflective white crystals. Since their red blood cells are transporting very little oxygen, Delia says the frogs likely have "some alternative process that allows them to keep their cells alive during transparency." Then, at night, when the frogs become active, "feeding and mating, going about their regular business," the vitreous amphibians release their red blood cells back into circulation.

Taboada says the frogs "pack roughly 90% of their red blood cells in a really, really small volume. Normally, those conditions can trigger some clotting disorders." The researchers say that knowing how the glassfrogs avoid a blood clotting cascade could pave the way for new anticoagulants for humans. **By Ari Daniel**
26 December 2022 Sent to FATS by Andrew Nelson
https://www.npr.org/people/297147967/ari-daniel
https://www.npr.org/2022/12/26/1145523973/glassfrog-hides-its-blood-glass-frogs

The FATS meeting commences at 7 pm, (arrive from 6.30 pm) and ends about 10 pm, at the Education Centre, Bicentennial Park, Sydney Olympic Park, Homebush Bay. FATS meetings are usually held on the **first Friday of every EVEN month** February, April (**except Good Friday 7/4/2023**), June, August, October and December. **OUR APRIL MEETING WILL BE HELD ON 31 MARCH 2023.** Call, check our web site, Facebook page or email us for further directions. We hold 6 informative, informal, topical, practical and free meetings each year. Visitors are welcome. We are actively involved in monitoring frog populations, field studies and trips, have displays at local events, produce the newsletter FROGCALL and FROGFACTS information sheets. FATS exhibit at many community fairs and shows. Please contact Events Coordinator Kathy Potter if you can assist as a frog explainer, even for an hour. No experience required. Encourage your frog friends to join or donate to FATS. Donations help with the costs of frog rescue, student grants, research and advocacy. All expressions of opinion and information in FrogCall are published on the basis that they are not to be regarded as an official opinion of the FATS Committee, unless expressly so stated.

FATS ON FACEBOOK: FATS has almost 4,400 Facebook members worldwide. Posts vary from husbandry, disease and frog identification enquiries, to photos and posts about pets, gardens, wild frogs, research, new discoveries, jokes, cartoons, events and habitats from all over the world. The page was created 11 years ago and includes dozens of information files – just keep scrolling to see them all. https://www.facebook.com/groups/FATSNSW/

RESCUED FROGS are at our meetings. Contact us if you wish to adopt a frog. A cash donation of $50 is appreciated to cover care and feeding costs. Sorry we have no EFTPOS. FATS must sight your current amphibian licence. NSW pet frog licences, can be obtained from the NSW Department of Planning, Industry and Environment (link below). Please join FATS before adopting a frog. This can be done at the meeting. Most rescued frogs have not had a vet visit unless obviously sick. Please take you new, formerly wild pet to an experienced herpetological vet for an annual check-up and possible worming and/or antibiotics after adoption. Some vets offer discounts for pets that were rescued wildlife.

https://www.environment.nsw.gov.au/licences-and-permits/wildlife-licences/native-animals-as-pets/frog-keeper-licences

FATS has student memberships for $20 annually with electronic FrogCall (but no hard copy mail outs). https://www.fats.org.au/membership-form

Thank you to the committee members, FrogCall supporters, talented meeting speakers, Frog-O-Graphic competition entrants, event participants and organisers David, Kathy and Harriet Potter, Sarah and Ryan Kershaw. The FrogCall articles, photos, media and webpage links, membership administration and envelope preparation are greatly appreciated. Special thanks to regular newsletter contributors: Robert Wall, Karen & Arthur White, Andrew Nelson, Wendy & Phillip Grimm, Marion Anstis and Punia Jeffery.

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FIELDTRIPS

PLEASE NOTE: Due to a myriad of circumstances, we have had to make significant changes to our advertised fieldtrips this season. Please read the following details carefully, and ring me if there is any doubt about any of the following changes. Many apologies for any inconvenience. As per our customary procedure, please be sure to always ring and confirm, in the last few days, whether these fieldtrips are proceeding or have been cancelled. Phone 02 9681 5308 for further details.

8 PM 28 January Homebush Bay Leader: Josie Styles

Meet in the carpark of Wentworth Common. The carpark is in Marjorie Jackson Parkway, about 150m from the intersection with Bennelong Parkway. Josie has accumulated vast experience as a professional biologist. She is well-acquainted with the Bell Frogs of Sydney Olympic Park as she previously spent many years with the Australian Museum monitoring the Bell Frog population here. Tonight, she will share her vast experience of this site, and will discuss some of the interesting trends occurring here.

The Sydney Olympic Park precinct is known for its population of endangered Green and Golden Bell Frogs. The frogs here soared to public prominence during the planning and construction of the Sydney Olympics venue. These frogs had long-occupied this derelict and largely-forgotten site. The Bell Frogs were facing an uncertain future in the face of a construction project that was perhaps the largest ever undertaken in Australia. The public watched as degraded wetland sites were enhanced to ensure the long-term survival of Bell Frogs. This recovery program was necessary to fulfil environmental obligations to the International Olympic Authority and to placate an international audience that had been given many desperate assurances by the Government that Sydney would be the "Green Games". Tonight, we will look at how the Bell Frogs are faring a twenty-odd years later.

Saturday 11 to Monday 13 February Smiths Lake Camp-Out Leaders: Karen and Arthur White

Unlike our usual Friday-Sunday schedule, this fieldtrip begins on SATURDAY and concludes MONDAY! Ring Karen and Arthur White on 02 9599 1161 for bookings and information. Our usual reservation procedure is in place. Cost is a **non-refundable** $20 per person, per night. Phone Karen White white.kazzie@gmail.com by Sunday 29 January, indicating that you (and how many others in your group) want to attend plus what day you intend to arrive. Karen will let you know on the phone if there is a vacancy. Leave a voice message and email her if she is unable to answer the phone. Payment is required by 3 February. **Account Name: Frog and Tadpole Study Group BSB 082 342 Account No. 285 766 885** Karen will send you confirmation of your booking when your payment has been received. The reserve list of people will be contacted after the 4th February. If you are contacted and still wish to attend, you will need to forward your payment as soon as possible to guarantee your place. We think that this is the fairest way to ensure that everyone, especially those who have never been to Smiths Lake field trip, get a chance to go.

7.45 PM 18 February West Head, Ku-ring-gai National Park Leader: Cassie Thompson

Meet at the Duckholes Picnic Area in West Head Rd, near the corner of McCarrs Creek Rd, Terrey Hills.

Research shows that *"......all roads, even minor service trails, have a disproportionate and negative impact upon aquatic environments and adjoining bushland"*. Problems of silting, re-routing of water-flows, increased access for both native and feral predators and the inadvertent introduction of pollutants, weeds and disease all become evident. Roads can be responsible for the significant fragmentation of habitat. Subtle changes in the micro-climate may also occur. Often, frogs are amongst the first to suffer. While incidences of roadkill are generally more obvious to the public, tonight we will consider some of the more insidious and far-reaching impacts of roads and drainage upon our bushland and wetland environments.

Cassie is a Biodiversity Officer with Transport For NSW. She is perfectly placed to show us some of the unique frogs of West Head. She will also explain the impacts of roads, bridges and other developments on our wildlife, and what mitigation measures can be taken in the planning stages of new infrastructure works.

In the event of uncertain frogging conditions (e.g. prolonged/severe drought, hazardous and/or torrential rain, bushfires etc.), please phone 02 9681 5308. Remember, rain is generally ideal for frogging! Children must be accompanied by an adult. Bring enclosed shoes that can get wet (gumboots are preferable), torch, warm clothing and raincoat. Please be judicious with the use of insect repellent – frogs are very sensitive to chemicals! Please observe all directions that the leader may give. Children are welcome, however please remember that young children especially can become very excited and boisterous at their first frogging experience – parents are asked to help ensure that the leader is able to conduct the trip to everyone's satisfaction. All fieldtrips are strictly for members only – newcomers are however, welcome to take out membership before the commencement of the fieldtrip. All participants accept that there is some inherent risk associated with outdoor fieldtrips and by attending agree to; a release of all claims, a waiver of liability, and an assumption of risk.