CHAPTER 14-3
GROUND-DWELLING ANURANS

Janice M. Glime and William J. Boelema

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Figure 1. ***Nannophryne variegata*** (previously *Bufo variegatus*) peering from a bed of the dung moss ***Tetraplodon mnioides*** in southern Chile. This toad is most likely only a casual visitor to the ***Tetraplodon***, although the attraction of these moss capsules for flies might make it an attractive feeding location for the toad. Photo by Filipe Osorio, with permission.

Peatland Habitats

Peatland habitats have been considered inhospitable for many species of frogs due to their acidity. Some frogs are tolerant enough to breed in the ***Sphagnum*** pools, but for others, mortality is too high. However, the ***Sphagnum*** mat and associated bryophyte serve other roles in the life cycles of these amphibians (Figure 1).

In Australia, the **Sphagnum Frog**, ***Philoria sphagnicolus*** (**Limnodynastidae**; Figure 2), has good reason for its name. This frog produces large eggs that are embedded in a foamy jelly (Debavay 1993). The male excavates a shallow burrow in clumps of ***Sphagnum*** or under stones on the forest floor. The females deposit the eggs in these burrows. The tadpoles complete development into adults within the nest. It is in small numbers worldwide and is on the IUCN red list of endangered species.

Figure 2. ***Philoria sphagnicolus***, the **Sphagnum Frog**. Photo by Evan, through Wikimedia Commons.

Mazerolle (2005) determined that male calling indicated that upland ponds were preferred by frogs over bog ponds, with calls emanating from 75% of the upland ponds, but only from 25% of the bog ponds, supporting the notion that the bog ponds may be too acid. None of the minnow traps in bog ponds caught tadpoles, whereas 58% of the upland ponds had at least one trapped tadpole. Several other studies likewise found few successful attempts of amphibians to breed in peatlands (Saber & Dunson 1978; Dale *et al*. 1985; Karns 1992b).

Furthermore, Mazerolle (2005) found no evidence that frogs moved from the forest to the bog in the summer, suggesting that the bog was not a significant refuge. However, there was back and forth movement between the bog and the upland, suggesting that the bog may provide a site for rehydration at times. Karns (1992a) and Mazerolle (2001), observing a number of amphibians, found that amphibians increased in bogs following the breeding season, so perhaps at least some frogs and other amphibians use them as summer sites.

But, it appears that **Green Frogs (*Lithobates clamitans*;** Figure 3**)** will use ***Sphagnum*** for rehydration (Mazerolle 2005). In an experiment where frogs were given the choice of ***Sphagnum***, upland sifted sandy loam, and well water with a *p*H of ~6.5 (upland pond water), the frogs showed no discrimination between the ***Sphagnum*** and the upland media as a source for rehydration.

Figure 3. ***Lithobates clamitans*** sitting among ***Sphagnum***. Photo by Alexander McKelvy, with permission.

Nevertheless, it appears that ***Sphagnum*** (Figure 4) peatlands are not as inhospitable to amphibians as formerly thought. In the boreal peatlands of North America, one might find the **Northern Leopard Frog** (***L. pipiens***; Figure 4), **Wood Frog** (***Lithobates sylvaticus***; Figure 5), **Green Frog** (***L. clamitans***; Figure 3), **Mink Frog** (***L. septentrionalis***; Figure 6), **Spring Peeper** (***Pseudacris crucifer***; Figure 7), **Western Chorus Frog** (***P. triseriata***; Figure 8), and **Gray Treefrog** (***Hyla versicolor***; Figure 9-Figure 10) (Desrochers & van Duinen 2006).

In Maine, the **American Bullfrog** (***Lithobates catesbeianus***; Figure 11) and **Pickerel Frog** (***Lithobates palustris***; Figure 12) are often found, as well as **Wood Frog** (***L. sylvaticus***; Figure 5), **Green Frog** (***L. clamitans***; Figure 3), **Northern Leopard Frog** (***L. pipiens***; Figure 4), **Spring Peeper** (***Pseudacris crucifer***; Figure 7), and **Gray Treefrog** (***Hyla versicolor***; Figure 9-Figure 10) (Desrochers & van Duinen 2006). Stockwell and Hunter (1989) also examined peatland amphibians in Maine, USA, and found twelve amphibian species. Of these, 94% of the captures were anurans. The most abundant of these was ***Lithobates sylvaticus*** (**Wood Frog**; Figure 5), comprising 59% of the captures. ***Lithobates clamitans*** (**Green Frog**; Figure 3) was the second most abundant, with 30% of the captures. Despite the presence of both sexes among adults in the Maine peatlands, Stockwell and Hunter concluded that none of the frogs except ***Lithobates sylvaticus*** (Figure 5) laid eggs in the peatlands. In Minnesota, the **American Toad** (***Anaxyrus americanus***; Figure 14) is added to the previous lists as one of the dominant species (Karns 1992a; Figure 13).

Figure 4. **Pickerel Frog**, ***Lithobates pipiens*** (Ranidae), among ***Sphagnum***. Photos by Janice Glime.

Figure 5. ***Lithobates sylvaticus*** on the moss ***Atrichum***. Photo by © John White, with permission.

Figure 6. **Mink Frog**, ***Lithobates septentrionalis*** (Ranidae). Photo by Twan Leenders, with permission.

Figure 7. **Spring Peeper**, ***Pseudacris crucifer*** (Hylidae). Photo by Matthew Niemiller, with permission.

Figure 8. **Mink Frog**, ***Pseudacris triseriata*** (Hylidae). Photo by Twan Leenders, with permission.

Figure 9. **Gray Treefrog**, ***Hyla versicolor*** (Hylidae). Photo by Janice Glime.

Figure 10. **Gray Treefrog**, ***Hyla versicolor*** (Hylidae), ventral view. Photo by Twan Leenders, with permission.

Figure 11. **American Bullfrog**, ***Lithobates catesbeianus*** (Ranidae). Photo by John D. Willson, with permission.

Figure 12. The **Pickerel Frog**, ***Lithobates palustris*** (Ranidae), on a bed of terrestrial mosses. Photo by Janice Glime.

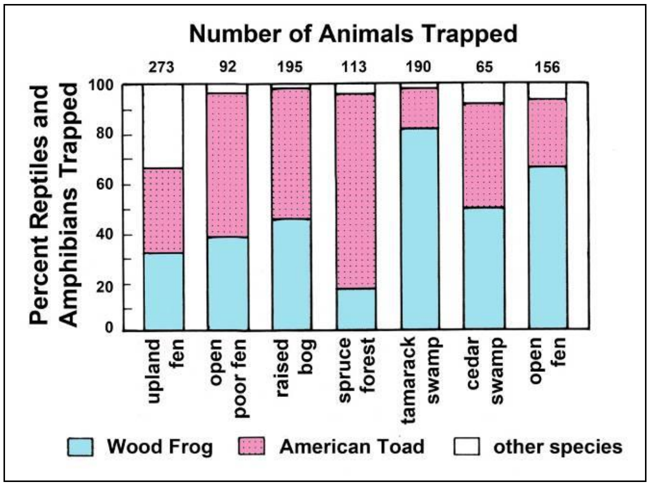

Figure 13. Comparison of percentage of **Wood Frogs** (***Lithobates sylvaticus***) with **American Toads** (***Anaxyrus americanus***) and other reptile and amphibian species trapped in various types of Minnesota peatlands. Redrawn from Karns 1992a.

The Tulula Wetlands, North Carolina, USA, have similar species to the boreal peatlands: **American Toad** (***Anaxyrus americanus***; **Bufonidae**; Figure 14), **Cope's Gray Treefrog** (***Hyla chrysoscelis***; Figure 15), **Green Frog** (***Lithobates clamitans***; Figure 3), **American Bullfrog** (***Lithobates catesbeianus***; Figure 11), **Wood Frog** (***Lithobates sylvaticus***; Figure 5), and **Spring Peeper** (***Pseudacris crucifer***; Figure 7) (Amphibians: Tulula Wetlands 2009). Knutson *et al*. (2000) suggest that the presence of **Pickerel Frog** (***Lithobates palustris***; Figure 12) is the best indicator of habitat quality in cold wetlands. Bog ponds can be especially enticing for amphibians because they harbor numerous insects and other invertebrates that serve as food (Desrochers & van Duinen 2006). Nevertheless, not all bogs seem to hold this attraction; in Estonia, frogs and toads are rare in bogs (H. Strijbosch in Desrochers & van Duinen 2006).

Figure 14. ***Anaxyrus americanus*** (**American Toad**) sitting on mosses. Photo by John D. Willson, with permission.

Figure 15. **Cope's Gray Treefrog**, ***Hyla chrysoscelis*** (Hylidae) with throat inflated while calling. Photo from US Geological Survey, through public domain.

Effects of *Sphagnum* Acidity

Because of its nearly continuous moisture, ***Sphagnum*** would seem to be an ideal habitat for frogs. But there is a caveat. ***Sphagnum*** acidifies its environment. And adult frogs typically avoid acidic conditions (Karns 1992a; Vatnick *et al*. 1999). Acidity can interfere with their development (Pough 1985; Leuven *et al*. 1986). Hence, it appears that low *p*H bog ponds might be of little or no importance in successful breeding and reproduction, but can be detrimental or lethal during tadpole development for most anurans (Gosner & Black 1957).

Rorabaugh (2008) found that the use of New Brunswick peatlands by the juvenile and adult **Northern Leopard Frogs** (***Lithobates pipiens***; Figure 4) peaked in August, a time when juveniles disperse from the breeding ponds (Mazerolle 2001). But *p*H is a problem for them. Tadpoles were unable to survive at *p*H less than 4, and even at less than *p*H 5.6 for more than 24 hours, mortality was high (Rorabaugh 2008).

As already suggested, ***Sphagnum*** can present problems for frogs because of the low *p*H conditions it creates. The **Wood Frog**, ***Lithobates sylvaticus*** (Figure 5), has tolerance to the lowest *p*H values measured in the New Jersey Pine Barrens, USA (Johnson 1985; Freda & Dunson 1986). In nine Maine bogs, Stockwell and Hunter (1985) found the **Wood Frog** to be the most common of the amphibians (59% of amphibians and reptiles). Karns (1979) never found tadpoles of this species at a *p*H lower than 5.0, although Johnson (1985) determined that eggs could develop normally at *p*H 4.0. Freda and Dunson (1985) showed that tadpoles of ***L. sylvaticus*** experienced lower sodium, chloride, and water concentrations in a low-*p*H pond (4.05-4.90) than did those from a nearby pond with a *p*H of 5.74-6.37. Higher sodium efflux occurred in both populations when placed in the lower *p*H pond, demonstrating the effect of low *p*H on ionic regulation in the tadpoles. This ability to exist in low *p*H water gives them an advantage – their predators are unable to survive the low *p*H, giving the tadpoles a huge advantage (See

discussion of overwintering and the anecdotal story by Dick Andrus).

Mazerolle and Cormier (2003) reported that they had captured **Green Frog** tadpoles in some of the bog ponds. However, they considered these ponds to be marginal, with an average *p*H of 3.67 (Mazerolle 2005), whereas the LC_{50} (*p*H at which 50% of frogs died) for **Green Frog** tadpoles in one study was 3.36 (Freda & Taylor 1992). Hence, the habitat was indeed marginal and indicated its importance despite its near-lethal *p*H. On the other hand, ***Lithobates clamitans*** (**Green Frog**; Figure 3) was among the most common (29%) of the amphibians and reptiles trapped in nine Maine, USA, bogs (Stockwell & Hunter 1985). In contrast, Brooks *et al*. (1987) found 13 amphibians and reptiles in peatlands of the Pocono Mountain region of Pennsylvania, USA, but none was common. The **Green frog** and ***Lithobates sylvaticus*** (**Wood Frog**; Figure 5) were not among the most common there. In Minnesota, the **Wood Frog** was the dominant amphibian (47% of all amphibian and reptile captures), but the **Green Frog** was conspicuously absent (Karns 1992a). Rather, in the Minnesota peatlands the **American Toad** (***Anaxyrus americanus***; Figure 14) was among the most common. Karns attributed this to more pools in the Maine peatlands, favoring the more aquatic **Green Frog**.

Not all amphibians are equally susceptible to the effects of low *p*H. Freda and Dunson (1986) found that in central Pennsylvania and the New Jersey Pine Barrens, USA, the **Jefferson Salamander** (***Ambystoma jeffersonianum*; Ambystomatidae**) and **Fowler's toad** (***Anaxyrus fowleri***, formerly *Bufo woodhousei*; Figure 16) were intolerant of water with a low *p*H. These two species had significantly higher mortality in ponds with low *p*H. In addition, ***Pseudacris triseriata***, ***P. crucifer***, ***Lithobates pipiens*** (Figure 4), ***Hyla versicolor*** (Figure 9-Figure 10), and ***Anaxyrus*** (=*Bufo*) ***americanus*** (Figure 14) were negatively affected by low *p*H water found in bog lakes. In laboratory experiments, ***Anaxyrus fowleri*** (Figure 16 and ***Hyla andersonii*** (**Pine Barren Treefrog**; Figure 17) exhibited significantly slower growth under acidic conditions, perhaps helping to explain the global decline in amphibians under the bombardment of acid rain. Freda and Dunson suggested that the small but erratic fluctuations of *p*H in the New Jersey ponds could contribute to their demise. They found that a *p*H change of only 0.2 units could alter hatching success. Contributions from acid rain could alter the *p*H sufficiently to kill sensitive eggs and larvae if the event were to occur at a critical time. In ponds where ***Sphagnum*** or other mosses are contributing H^+ ions, this additional input could to be lethal.

On the other hand, in these same locations the **Wood Frog** (***Lithobates sylvaticus***; Figure 5) and the **Pine Barrens Treefrog** (***Hyla andersonii***; Figure 17) tadpoles occurred in ponds with the lowest *p*H values, with the latter hatching at a *p*H as low as 3.70 (Freda & Dunson 1986). Ling *et al*. (1986) in Marquette County, Michigan, and Karns (1992b) in northern Minnesota, USA, found a similar tolerance for low *p*H in tadpoles of ***Lithobates sylvaticus*** (Figure 5). The larvae were seemingly unaffected when reared at *p*H as low as 3.0 (Ling *et al.* 1986). But further study is needed to explain the survival of ***Hyla andersonii*** at such low *p*H levels when the same authors (Freda & Dunson 1986) have demonstrated that low *p*H has a negative effect on its growth.

Figure 16. **Fowler's Toad** (***Anaxyrus fowleri***) sitting on ***Plagiomnium***. Photo by Twan Leenders, with permission.

Figure 17. ***Hyla andersonii*** (**Pine Barrens Treefrog**). Photo by Bruce Means, US Fish & Wildlife Service, with permission.

It is perhaps encouraging that proximal populations of ***L. sylvaticus*** (Figure 5) may differ. Karns (1992b) found that both embryos and larvae of ***L. sylvaticus*** from northern Minnesota peatlands had a greater tolerance for the low *p*H of bog water than did those that came from a circumneutral marsh in southern Minnesota. However, Karns concluded that the preference of this species for fen sites (higher *p*H) was due to being born there and not to avoidance of bog water.

Acid as a Refuge - *Rana arvalis* (Moor Frog, Ranidae)

The Moor Frog (***Rana arvalis***; Figure 18) occurs in many European countries. This frog can be the only frog species in some upland Lithuanian bogs (Ðireika & Staðaitis 1999). As many as 20 individuals may be found in 0.1 hectare. However, throughout Europe it inhabits a wide range of habitats. In Siberia it occurs primarily in open swamps.

Figure 18. The **Moor Frog**, ***Rana arvalis*** on ***Sphagnum***. Photo by Piet Spaans, through Creative Commons.

This is one of the few species that is able to breed in acid peat bogs (Figure 19) because the acidic water is not suitable for frog egg development in most species (Klaus Weddeling, Bryonet 26 March 2011). Šandera (pers. comm. 20 February 2011) suggested that the frogs may hide in mosses in the summer to maintain moisture. Extensive fishery and agriculture threaten the future of ***Rana arvalis*** (Figure 18) (Šandera *et al*. 2008.

Figure 19. ***Rana arvalis*** in amplexus with the male on top. Notice the difference in coloration between the male and female. Photo by Martin Šandera, with permission.

Moisture Refuge

The **Wood Frog** (***Lithobates sylvaticus***; Figure 5) also may use ***Sphagnum*** as a "refugium" when it is migrating to its summer habitat and during the daytime in forested wetlands (Baldwin *et al*. 2006). The moisture and protection from the sun permit it to survive its trek to its new home. At least in Maine, USA, forested wetlands with *Sphagnum* are important in their migratory success. It is time to let the world know that to save the frogs we may need to save the mosses!

As already discussed, frogs need moisture. Hence, Mazerolle (2005) investigated the use of ***Sphagnum*** bogs (peatlands) by **Northern Green Frogs, *Lithobates*** (=*Rana*) ***clamitans melanota*** (Figure 20), in New Brunswick, Canada, to look for indications that the low *p*H would deter them from use of the moist habitat of the bog.

Figure 20. **Green Frog**, ***Lithobates clamitans***. Photo by Tony Swinehart, with permission.

Burrows in the Bog Moss

The **Common Frog** in Europe (***Rana temporaria***; Figure 21) inhabits raised bogs, blanket bogs, and fens (Peatlands 2009). Ida Bruggeman (pers. comm. 5 February 2009) observed them in her own Netherlands garden peatland, where they sometimes would burrow into holes dug by **Green Frogs** (***Pelophylax***). They never seemed to dig their own holes, however. She was able to observe ***P. rubicundus*** digging a burrow in which it would sit for hours (Figure 22-Figure 24). It would return to the same burrow for several consecutive days.

Figure 21. ***Rana temporaria*** (**Common Frog**) mating. Photo by Richard Bartz, through Wikimedia Commons.

Figure 22. A green frog, ***Pelophylax ridibundus***, in a ***Sphagnum*** bank in the garden of Ida Bruggeman in The Netherlands. This one is resting in the burrow it dug. Photo by Ida Bruggeman, with permission.

Figure 23. **Marsh Frog**, ***Pelophylax ridibundus*** peering out of resting burrow in ***Sphagnum***. Photo by Ida Bruggeman, with permission.

Figure 24. An empty burrow of the green frog, ***Pelophylax ridibundus***, in a ***Sphagnum*** bank in the garden of Ida Bruggeman in The Netherlands. Photo by Ida Bruggeman, with permission.

Figure 25. **European Common Spadefoot Toad** (***Pelobates fuscus***). Photo by Christian Fischer, through Wikimedia Commons.

Retreats – Mosses Instead of Sand

The **European Common Spadefoot** (***Pelobates fuscus***; Pelobatidae; Figure 25) can occur in ***Sphagnum*** peatlands, where its retreat-making behavior might be useful (Stachyra & Tchórzewski 2004). But its typical habitat is farmland, dunes, and pinewoods (Bosman & van den Munckhof 2006). This spadefoot is also known as the garlic toad because of the odor it emits as part of its noxious exudation defense mechanism. Like so many species of amphibians, this one is also disappearing. Its need for a suitable terrestrial habitat is emphasized by its predominantly beetle diet (Nicoară *et al*. 2005).

A Toxic Bog-dweller – *Bombina bombina* (European Fire-bellied Toad, Bombinatoridae)

Native to lowland swamps and wetlands (IUCN 2011), the **European Fire-bellied Toad** is named ***Bombina bombina*** (Figure 26). [**Tautonyms** (specific name repeats the generic name) are acceptable in zoological nomenclature, but are cause for rejection in botanical nomenclature and word processor grammar checkers!] ***Bombina bombina***, common in eastern and central Europe (IUCN 2011) and from the Balkans across central and eastern Asia (Staniszewski 1998), is one of the amphibians that inhabit the highland and transitional ***Sphagnum*** peatlands in Poland (Stachyra & Tchórzewski 2004), as well as bogs in other areas. It is not a true toad, but does have a warty skin. Its name derives from its bright red-orange belly that acts as warning coloration against predators, especially as it rears up to expose its bright underbelly. Despite its toxic skin, this and several other species of fire-bellied toads are kept as pets.

When it is time to shed its skin, this slightly toxic (to humans) toad first bloats itself, making a coughing sound, then tears off its skin with its mouth and eats it for added nutrition (Wikipedia 2008). When endangered, it rolls over, exposing its colorful belly, and covers its eyes with its feet (AmphibiaWeb: *Bombina bombina* 1999). In other cases, it may arch its back and expose its brightly colored underside (Wikipedia 2010). Despite its threatening color display and distasteful poison, it still is frequently eaten.

Figure 26. **European Fire-bellied Toad** (***Bombina bombina***). Photo by Mark Szczepanek, through Wikimedia Commons.

BSTI is a protease in the skin of these frogs that is a trypsin and thrombin inhibitor (Mignogna *et al*. 1996). Mignogna and coworkers suggest that the role of this protease in the skin is to prevent the premature release or breakdown of skin peptides. But it seems likely that the protease may also have toxic properties against predators. Certainly, inhibition of thrombin can cause excessive

bleeding, but the authors did not test this possibility in would-be predators. Despite its use of many kinds of habitats, the disappearance of wetlands is the greatest threat to this species (AmphibiaWeb: *Bombina bombina* 1999).

Ground-Dwellers: Bufonidae (Toads)

Although a number of amphibians have the common name of toad, only members of the Bufonidae are true toads. They differ from all other amphibian families by the presence of a pair of **parotoid** glands (Figure 27) at the back of the head, behind the eyes. Most of the Bufonidae have conspicuous warts, but so do members of many other Anuran species. Otherwise, they generally resemble frogs.

North American toads have recently been moved to a different genus, based on genetics and cladistics (Naish 2009), from the well known genus ***Bufo*** to ***Anaxyrus***, a genus restricted to the North American continent. However, this move is not acceptable to all herpetologists because it makes the remaining genus ***Bufo*** paraphyletic (Pauly *et al*. 2004, 2009). Furthermore, morphological characters that unite the genus ***Anaxyrus*** and separate it from ***Bufo*** have not yet been elaborated. Nevertheless, I shall use ***Anaxyrus*** for the North American members where it is appropriate, but be aware that other genera have also been split off from ***Bufo*** as well.

Most of us know the toads from childhood and may have been told that we would get warts from handling them. But toads don't cause warts. They do, however, emit secretions that can be irritants to some people. Toads have a pair of **parotoid glands** (Figure 27) on the backs of their heads. These excrete an alkaloid poison when the animals are stressed. There is a variety of compounds in these, differing among species. The term **bufotoxin** refers to any of these. The most toxic of these is from the Cane Toad, *Rhinella marina* (previously *Bufo marinus*).

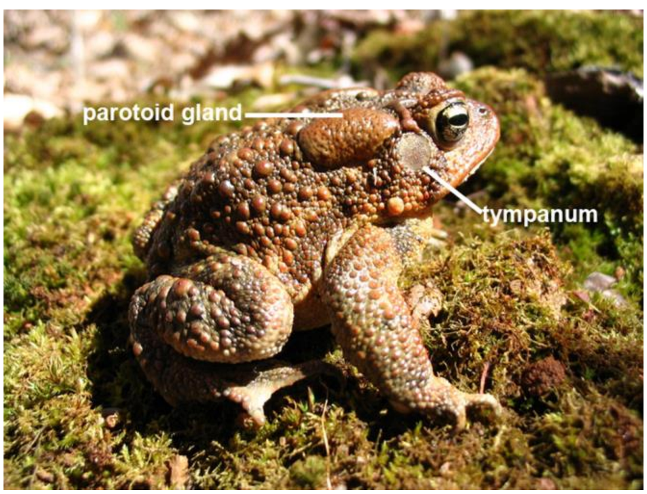

Figure 27. Head and thorax of the American Toad, ***Anaxyrus americanus***, illustrating the location of the parotoid gland and the tympanum, the external portion of the ear drum. Photo © Jason Gibson, with permission for academic use.

As already seen, toads certainly make use of bryophytes as hibernacula, where they spend the winter under the insulating blanket of clumps and thick mats. Toads spend less time in the water than do the true frogs. Hence, in addition to casual use, as is likely for ***Nannophryne variegata*** (previously *Bufo variegatus*) in Figure 1**,** we might expect somewhat different uses of the bryophytes than that seen for frogs.

Most toads lay their eggs in paired strings in open water (Figure 28) (Wikipedia 2015b). These eggs hatch into tadpoles except in ***Nectophrynoides***, whose eggs hatch directly into tiny toads.

Figure 28. ***Rhinella arunco*** (Bufonidae) strings of eggs. Photo © Danté B. Fenolio <www.anotheca.com>, with permission.

One of the strangest characteristics for toads is the ability of the male to change sex! These males have a **Bidder's organ** that can become an ovary under the right conditions (Wikipedia 2015b). But apparently this organ only becomes functional as an ovary when the testes are destroyed – an event most likely to occur in the lab (Wikipedia 2014). But it can also become functional when the testes are rendered non-functional by exposure to endocrine-disrupting chemicals. This may be somewhat adaptive in our polluted world.

Anaxyrus americanus (American Toad, Bufonidae)

Among the amphibians of the boreal peatlands in North America (Desrochers & van Duinen 2006) and the Tulula Wetlands in North Carolina, USA (Amphibians: Tulula Wetlands), one can find the widespread American Toad, ***Anaxyrus americanus*** (Figure 29-Figure 32). In Maine, USA, wetlands this species likewise occurred, but it was not abundant (Desrochers & van Duinen 2006).

It is likely that toads use bryophytes as part of a mosaic habitat. Their mottled browns and grays make them inconspicuous on the intermittent patches of soil. They can burrow under the bryophytes in winter to hibernate or burrow into them in summer to get cool or remain hydrated (Figure 30).

Terrestrial mosses may be more important than wetlands for toads. In the late autumn, I have more than once lifted a clump of moss for a collection, only to find a very quiet toad (**American Toad**, ***Anaxyrus americanus***; Figure 29) under the moss. I presumed that these animals were spending the winter there. It would seem likely that the moss would help to protect them from desiccation and cold during the winter months, and perhaps even lessen evaporative cooling. Kate Frego (personal communication 12 January 2008 and Bryonet 3 February 2009) relays this interesting story from Crepieul Township, northern Ontario (near town of Chapleau), Canada. She was working in an

upland white spruce post-fire forest, ~130 years old, with a thick carpet of ***Pleurozium schreberi*** (Figure 33). "It was quite startling! I arrived at my site before the snow melted (on purpose) and watched everything come to life. One day the ***Pleurozium*** carpet around some tree bases was literally pulsating. I was somewhat spooked, and watched for some time, from a distance!! Eventually there was a little break in the moss, and these toad feet 'swam' out, and a great fat **American Toad** pulled itself out of the opening it had made." The toad sat on the moss in the warm sun, then hopped off toward the pond. She estimates that the toad had been about 12 cm below the surface of the mosses. The pond nearby was full of **American Toad** tadpoles every year she was there, suggesting that this was an important breeding and overwintering habitat.

Figure 29. **American Toad**, ***Anaxyrus americanus***, peering through the sporophytes of ***Polytrichum***. Photo by Josh Vandermeulen, with permission.

Figure 30. Toad (***Anaxyrus***) burrowed into moss in July in the Adirondacks, eastern USA, perhaps to keep its skin moist. Photo by Sean Robinson, with permission.

To be of use to the toads, breeding habitats must be near water – ditches, pools, even vernal ponds. Eggs are laid in a long string or tube and young are hatched as tadpoles (Figure 34).

Figure 31. The common **American Toad**, ***Anaxyrus americanus***, on a bed of the moss ***Atrichum***. Photo by Twan Leenders, with permission.

Figure 32. **American Toad**, ***Anaxyrus americanus***, showing nostril, eye, tympanum, and warts. Photo by Janice Glime.

Figure 33. ***Pleurozium schreberi***, a moss where toads can emerge in the spring. Photo by Janice Glime.

Figure 34. Eggs and tadpoles of the common **American Toad *Anaxyrus americanus*** in a shallow pool. Photo by Janice Glime.

Anaxyrus boreas (Western Toad, Bufonidae)

Bartelt *et al.* (2004) used radio transmitters to demonstrate the movement patterns of 18 **Western Toads** (***Anaxyrus boreas***, previously *Bufo boreas*; Figure 35). The toads seemed to move at times and through habitats that maximized moisture conservation and selected moss cover for their movements 1.8% of the time, despite a frequency of this cover type that was near zero. Browne and Paszkowski (2010a) found that in north-central Alberta, Canada, this species used moss-covered peatland, among other habitats, during the foraging period, but they did not report use of mosses for hibernation (Browne 2010; Browne & Paszkowski 2010b).

Figure 35. ***Anaxyrus boreas*** on the forest floor where moss cover can help to maintain skin moisture. Photo by William Flaxington, with permission.

Bull (2009) found a similar preference by juveniles for mossy areas in Oregon. Young toads dispersed up to 2720 m from their site of birth within only 8 weeks after entering their adult stage. During their movement to their new summer home, they were subject to desiccation, predation (especially by birds), death by car, cattle trampling, and chytridiomycosis infection. Having mosses at 85% of the plots where juveniles occurred, compared to presence of mosses in only 3% of the area may only be a correlation with the need for the water. Mosses may have occurred in wetter areas. Nevertheless, Bull suggested that the mosses helped to provide protection from desiccation.

Bufo bufo (European Common Toad, Bufonidae)

The **European Common Toad** (***Bufo bufo***; Figure 36), which also extends into northern Africa, may be one of the few amphibians to eat bryophytes. Javier Martínez Abaigar (February 2009 pers. comm.) tells of finding bits of leaves of aquatic bryophytes, such as ***Fontinalis antipyretica*** (Figure 37), ***Chiloscyphus polyanthos*** (Figure 38), and other unidentified species, in the guts of tadpoles of this toad. Was this truly intended as food? Or did the rasping mouth tear these as it scraped algae from the leaves, or did they enter as detritus among the other edibles nestled among the bryophytes or on the bottom? In any event, I thought this would be worth exploring as a potential dispersal mechanism for the moss, but Javier says the tadpoles are confined to small, quiet pools and would provide no more dispersal than the fragment would have without the help of the tadpole, unless of course, the tadpole gets eaten.

Figure 36. Brown expression of the **European Common Toad**, ***Bufo bufo***, amid herbaceous plants and bryophytes. Photo by Milan Kořínek, with permission.

Figure 37. ***Fontinalis antipyretica***, shown here exposed out of water in early autumn, is an occasional food source for the **European Common Toad**, ***Bufo bufo***. Photo by Janice Glime.

Figure 38. ***Chiloscyphus polyanthos***, an occasional food source for the **European Common Toad**, ***Bufo bufo***. Photo by Des Callaghan, with permission.

This **European Common Toad** excretes a **bufagin** toxin that deters most predators. Unfortunately for the toad, grass snakes and hedgehogs, both predators on toads, are immune to it (Wikipedia 2015a). Females typically return to the pond where they were born to lay eggs in the spring. As adults, they are land-born, eating insects and other small invertebrates, but turnabout is fair play – larger toads may also eat grass snakes. These toads are on the IUCN (2010) red list of endangered species. They are often vulnerable when crossing roads to reach breeding grounds, causing some environmental groups to build tunnels under the road to permit safe crossing (Figure 39). Mazerolle (2005) indicates that drainage ditches may offer similar facilitation for frogs.

Figure 39. Tunnel under road to permit safe passage of the **European Common Toad** ***Bufo bufo*** to and from its breeding grounds. Photo by Christian Fischer, through Wikimedia Commons.

Incilius coniferus (formerly ***Bufo coniferus***, Evergreen Toad, Bufonidae)

Incilius coniferus (formerly *Bufo coniferus*; **Evergreen Toad)** (Figure 40) is listed as a species of least concern (IUCN 2011), but it seems to be largely ignored. A Google search found nothing except its occurrence on several species lists. Its known distribution was on both Atlantic and Pacific slopes in east-central Nicaragua, Costa Rica, and Panama and into the Pacific lowlands of Colombia and northern Ecuador (Frost 2011).

Figure 40. ***Incilius coniferus*** (**Evergreen Toad**) blending with a bed of mosses and liverworts. Photo by Brian Gratwicke, through Creative Commons.

I could find nothing to indicate this species makes use of bryophytes for a habitat element, but the picture shown here (Figure 40) suggests that it might, and that it certainly would have good camouflage if it did. But this is not its only coloration. Most individuals are yellow-green to olive green, or even dull brown or gray, with little mottling, or sometimes with white or dark blotches (Savage 2002). The presence of warts helps to disrupt its coloration and facilitate blending with its environment. This individual seems to have combined these in just the right way to blend with the surrounding bryophytes. These color patterns help it to blend with its humid lowland forest and premontane habitat, where it is known up to 1550 m (Savage 2002). But it most likely also helps make it less conspicuous when it climbs, as much as several meters (Duellman & Schulte 1992; Savage 2002).

A further suggestion, besides its coloration, that bryophytes might be an important part of its habitat is that it eats ants and mites (Toft 1981), both of which can be abundant among bryophytes. Its oviposition doesn't offer any clues – it occurs at the beginning of the wet season, and the frogs place the eggs in temporary pools or depressions (Crump 1989). Tadpoles emerge from the eggs five days later, attesting to its aquatic, rather than terrestrial, affiliations. Is the coloration of ***Incilius coniferus*** (**Evergreen Toad;** Figure 40) just a co-incidence?

Pseudepidalea viridis (Green Toad, Bufonidae)

The green toad, ***Pseudepidalea viridis*** (previously *Bufo viridis*) (Figure 41) is a common inhabitant of peatlands in high elevation and transitional peat bogs in Poland (Stachyra & Tchórzewski 2004). This frog breeds over several months, presumably as a mechanism for greater survival in habitats that may dry up before tadpoles mature (Kovács & Sas 2009). When food gets scarce, the tadpoles may become cannibalistic, a phenomenon known in other tadpoles such as ***Anaxyrus boreas*** (Figure 35) (Jordan *et al*. 2004).

Figure 41. The **Green Toad**, ***Pseudepidalea viridis***, a peatland inhabitant. Its coloration suggests it might blend well with the mix of moss tops and dark spaces in the peatland. Photo by © John White, with permission.

Epidalea calamita (Natterjack Toad, Bufonidae)

Although this European frog, a close relative of ***Pseudepidalea viridis*** (Figure 41), inhabits sand dunes and gravel quarries (AmphibiaWeb: *Bufo calamita* 2006), the **Natterjack toad**, ***Epidalea calamita*** (previously *Bufo calamita*) (Figure 42-Figure 43), is likewise a common inhabitant of peatlands in high elevation and transitional peat bogs in Poland (Stachyra & Tchórzewski 2004). This is the only species of toad native to Ireland, where it lives near pools that stay warm (Wikipedia 2016). In The Netherlands, Strijbosch (1979) found this species selected the most eutrophic sites during its aquatic stage. Elsewhere in Europe it is common in heathlands.

Figure 42. Very young **Natterjack Toad**, ***Epidalea calamita*** climbing among the mosses. Photo by Piet Spaans, through Creative Commons.

In southern Britain, these toads avoid *Calluna* heaths, but they spend their entire lives in open areas where bare sand or short bryophyte turf dominates the landscape (Banks *et al*. 1993). It is interesting that introducing the cyprinid fish known as **ide** or **orfe** (***Leuciscus idus***; Figure 44) to the breeding pools reduced the predatory invertebrates, increasing survival of the tadpoles. Unfortunately, adults, especially males, fell prey to the grass snake (***Natrix natrix***; Figure 45).

Figure 43. Adult **Natterjack Toad**, ***Epidalea calamita***, at night. Photo by Christian Fischer, through GNU Free Documentation License.

Figure 44, ***Leuciscus idus*** (**ide** or **orfe**), a fish that reduces predators on the tadpoles of ***Epidalea calamita*** by eating the predators. Photo through Wikimedia Commons.

Figure 45. ***Natrix natrix*** (**Grass Snake**), a predator on adult **Natterjack Toads** (***Epidalea calamita***). Photo by Karl Larsaeus, through Wikimedia Commons.

Beebee (1977) attempted to determine the cause of 40 years of decline in this species. It is interesting that it was the inland heaths that had the greater decline, compared to the dunes. Climate change, human activity, and development did not seem to be a problem. Rather, large-scale changes in the heathland flora were responsible. Grazing stopped and forestry activity increased, permitting the invasion by taller vegetation and greater shade. These conditions were unsuitable for the **Natterjack Toad**, but a greater problem was the invasion of its competitor, ***Bufo bufo*** (Figure 36).

Leptophryne cruentata (Indonesia Tree Toad, Bleeding Toad, Bufonidae)

Leptophryne cruentata (Figure 46-Figure 47) is a true toad distributed in Southeast Asia, primarily Indonesia. Kusrini *et al*. (2007) found fifteen frogs hidden in a crevice covered by mosses in the wall of a waterfall. Its habit of hiding could explain its elusiveness. It is listed as critically endangered, at least partly because of the volcanic eruption of Mount Galunggung in 1982 (Wikipedia: Bleeding Toad 2008) that buried a large part of its range.

Figure 46. **Indonesian Tree Toad**, ***Leptophryne cruentata***, showing a pink-purple variety. Photo by Frank Yuwono, with permission.

Figure 47. ***Leptophryne cruentata***, the **Indonesian Tree Toad**, showing a red and yellow spotted variety. Photo by Georg Moser, with permission.

Atelopus zeteki (Panamanian Golden Frog, Bufonidae)

In tropical wet forest stream habitats, the critically endangered Panamanian Golden Frogs (***Atelopus zeteki***; Figure 48-Figure 49) can be found among mosses (Hong 2007; Lindquist *et al*. 2007). Technically a toad (Bufonidae), these amphibians look more like a tree frog. They may climb as much as 3 m near water falls, where they perch on large moss-covered boulders. But beware of these beautiful frogs. Their skin contains a highly toxic alkaloid that is an analog of **saxitoxin** (Fuhrman *et al*. 1969; Brown *et al*. 1977) and has the ability to block sodium channels in the nervous system (Yotsu-Yamashita *et al*. 2004).

Figure 48. **Panamanian Golden Frog** (***Atelopus zeteki***) sitting among bryophytes and ferns beside a stream. Photos by © John White, with permission.

Figure 49. ***Atelopus zeteki*** (**Panamanian Golden Frog**) with a conspicuous yellow dorsal view while sitting on a bed of moss. Photo by Dave Pape, through Wikimedia Commons.

Figure 50. Habitat of ***Atelopus zeteki*** (**Panamanian Golden Frog**). Photo by Brian Gratwicke, through Creative Commons.

Atelopus loettersi (Bufonidae)

This newly described species was located on the Amazonian slopes of southern Peru at 400-1000 m asl (De la Riva *et al*. 2011). Only tiny juveniles could be found, dwelling on mosses covering a large rock wall along a river bank. That appears to be all that is known about this species at this time.

Toads in the Trees: Bufonidae

Rhinella tacana (formerly *Chaunus tacana*, Bufonidae)

First named in 2006 (Padial *et al* 2006), ***Rhinella tacana*** (Figure 51) lives in the humid forest at only one known location in Bolivia at 1500 m asl (Frost 2011). It lives in Andean valleys and Amazonian slopes. Within its habitat, it climbs moss-covered tree trunks and rests on leaves or trunks at 1-4 m height (Padial *et al*. 2006). Its reproduction is unknown and too little is known about it for classification in the IUCN redlisting (IUCN 2011).

Figure 51. ***Rhinella tacana***, a toad that climbs mossy tree trunks in Bolivia. Photo by Sean Michael Rovito, with permission.

Ansonia latidisca (Borneo Rainbow Toad, Sambas Stream Toad, Bufonidae)

The **Sambas Stream Toad** (Figure 52) had not been seen since 1924 when Dr. Indraneil Das and his research team set out in 2011 to find it (Lin 2011). Just imagine the excitement of his graduate student, Pui Yong Min, who discovered it near the border of Indonesia and Malaysia, perched 2 m above ground on a moss-covered branch. But at this time, that is about all we know about it, except that it is a beautiful toad that would be a desirable pet for that reason. Therefore, to protect it, the location will not be published.

Figure 52. ***Ansonia latidisca***, **Borneo Rainbow Toad**, perched on mosses 2 m up in a tree. Photo by Indraneil Das, with permission.

Eastern Hemisphere Mossy Habitats

Arthroleptidae

Leptodactylodon albiventris (**Whitebelly Egg Frog;** see Figure 53) is endemic to Cameroon, Africa, in subtropical and tropical moist lowland forests, moist montane areas, rivers, and rocky areas (Amiet 2004). Living at 300-1000 m asl (Frost 2011), this species calls day and night from hidden locations; it finds a thin layer of water flowing under rocks or other cover and can only be located by removing the rocks, mosses, or looking among submerged roots (De la Riva *et al*. 2001).

Figure 53. ***Leptodactylodon*** sp. (**Whitebelly Egg Frog**) on leaf, member of a genus where some species hide under mosses in flowing water. Photo by Ignacio De la Riva, with permission.

Myobatrachidae

Pseudophryne (Myobatrachidae)

Several species in this genus, which is endemic to Australia, are known to be bryophyte inhabitants. Unique

to ***Pseudophryne*** species among the anurans, part of their defense is accomplished by a class of indolic alkaloids called **pseudophrynamines** (PS's). These compounds appear to be produced internally, either by the frog itself or by symbiotic organisms living within the frog (Smith et al 2002). In addition to these toxic alkaloids, they also possess **pumiliotoxins** (PTX's). The latter are found in all genera worldwide if those anurans (frogs & toads) contain lipophilic alkaloids. The PTX's appear to have a dietary source, with lab-reared animals lacking the compound. It is subsequently incorporated into the skin. An interesting consequence of high levels of this skin toxin is that it seems to inhibit the production of PS.

Pseudophryne corroboree & *P. pengilleyi* (Corroboree Frogs, Myobatrachidae)

The genus ***Pseudophryne*** is known only from Australia. The alpine species ***Pseudophryne corroboree*** (Figure 54) in New South Wales, Australia, has been split into two species with the northern one separated into ***P. pengilleyi*** (Osborne *et al.* 1996; Figure 55). Corroboree is the aboriginal name for a group meeting and the name of the frogs refers to the habit of gathering in large groups to form a chorus.

Figure 54. ***Pseudophryne corroboree***, an alpine corroboree frog from New South Wales, Australian, shown here in its peat moss (***Sphagnum***) habitat. Its bumblebee coloration is a better warning coloration than a camouflage. Photo by Scott Robinson <www.ifrog.us>, with permission.

Figure 55. The **Northern Corroboree Frog**, ***Pseudophryne pengilleyi***, in its native peatland habitat in northern New South Wales, Australia. Photo by Ken Thomas, with permission.

Both live in peatlands and often deposit their 10-38 eggs there (Pengilley 1973) in locations that become seasonally inundated. The male makes deep burrows in the ***Sphagnum*** or other substrate and proceeds to call from there to attract females. Males generally stay with the eggs for two-four weeks. Like several other moss-dwelling frogs, females may deposit several clutches of eggs, thus making smaller clutches and increasing the oxygen availability to all the eggs (Woodruff 1976). The southern species, ***P. corroboree*** (Figure 54), is in danger of extinction (Project Corroboree). Efforts to save the species include captive breeding.

Pseudophryne semimarmorata (formerly *Pseudophryne bibroni*) (Southern Toadlet, Myobatrachidae)

Pseudophryne semimarmorata (Figure 56) occurs in the extreme southeast of South Australia, southern Victoria, and eastern Tasmania, where it enjoys the status of least concern – an unusually safe designation for a small frog (IUCN 2010). It is called a toadlet due to its warty appearance, but it is not a true toad. Its typical habitats are dry forest, woodland, shrubland, grassland, and heath (Frogs of Australia 2011). The frogs hide under leaf litter or other debris (a designation that includes bryophytes) in depressions and other moist areas. They move about in their habitat by walking instead of the familiar hop we typically think of for frogs, but then many (most?) frogs walk or crawl when not trying to escape something.

Figure 56. ***Pseudophryne semimarmorata***, a species that hides under mosses in southern Australia. Note the absence of a tympanum behind the eye. Photo by John Wombey, through Creative Commons.

Males call, from burrows that the males construct, in late summer and autumn (FrogsAustralia 2005). But this species lacks any structural hearing organ (Figure 57) (Loftus-Hills 1973b; Parks & Wildlife Service, Tasmania 2010). One hypothesis is that they sense the sounds through the vibrations of the skull bones, a concept supported by the correlation between head width and auditory threshold (Loftus-Hills 1973a). They cease calling if ***Crinia victoriana*** begins calling nearby, and resume when this competing species stops (Littlejohn & Martin 1969). These two species use the same frequency band (~2500 Hz), so cessation of the call increases the efficiency of their communication.

Figure 57. ***Pseudophryne semimarmorata*** on a bed of mosses. Note the absence of a tympanum behind the eye. Photo by John Wombey, through Creative Commons.

It has an unusual reproductive behavior that befits its amphibious habitat. The nesting burrows, dug by the males, are located near water or boggy ground (FrogsAustralia 2005). The females lay their large eggs in loose clumps under litter in these shallow burrows (Frogs of Australia 2011). These must be located where they will later be flooded so that the aquatic tadpoles have a place to swim. The unusual aspect is that the eggs of one female may have up to eight different fathers and be placed in as many different nests (O'Brien 2011). These fathers stay with their fertilized eggs until they have developed into tadpoles (O'Brien 2011), a duty that lasts for at least 42 days (Parks & Wildlife Service Tasmania 2010). This promiscuous strategy by the females increases the chances that some of her eggs will be in nests that are suitably positioned for flooding at the right time (O'Brien 2011). If they are flooded too early, the eggs could be washed away, whereas if flooding is too late, the eggs can dry out. Since mosses often grow in such amphibious locations, they may play a role in the "debris" used for nesting and adult habitat.

Crinia nimbus & C. georgiana (Australian Moss Froglet, Myobatrachidae)

In Tasmania, you might hear what sounds like a ping-pong ball dropped on wood: took-tok-tok-tok-tok-tok, the call of the endemic **Australian Moss Froglet**, ***Crinia nimbus***, a cloud forest froglet (Wildlife Management 2014; Figure 58). The call of this common but narrowly distributed frog (southern mountains of Tasmania) is likely to come from its position under mosses or lichens in its nest, thus muffled by the overlying cover (Sopory & Hero 2008).

In ***Crinia nimbus***, the larval development time is greatly benefitted by temperatures as they increase from 5 to 15ºC (Mitchell & Seymour 2003). It would be interesting to learn whether the dark-colored mosses serve as black bodies to warm the habitat for these larvae in winter. If so, they could significantly increase survival because the larvae do not feed, and at 5ºC they can run out of yolk and die before reaching adulthood and food intake.

The **Australian Moss Froglet** requires mosses or lichens to maintain sufficient moisture for the development of its embryos (Mitchell 2002a). The female deposits 4-16 large eggs (Figure 59) in nests made from these in the subalpine regions of southern Tasmania (Mitchell & Seymour 2000). The frogs spend one year as larvae within any of about 10 species of mosses, lichens, and lycopods (Mitchell 2002b), and in southern Tasmania, this occurs under the snow (Mitchell & Seymour 2000). In laboratory experiments, embryos that experienced more drying than that experienced among the mosses had asymmetrical deformities and lower survivorship (Mitchell 2002a).

Figure 58. The **Australian Moss Froglet**, ***Crinia nimbus***, a small (up to 30 mm length) Tasmanian endemic that sounds like a ping-pong ball calling from its nest under mosses. Photo by Gerry Marantelli, compliments of the Amphibian Research Centre <http://www.frogs.org.au/>, with permission.

Figure 59. **Australian Moss Froglet**, ***Crinia nimbus***, eggs in their nest under mosses. Photo by Gerry Marantelli, compliments of the Amphibian Research Centre <http://www.frogs.org.au/>, with permission.

But moisture is not the only contribution of the moss. The thick gelatinous capsule around the eggs in this species affords further protection from desiccation, but it creates a formidable barrier to the entrance of oxygen (Mitchell & Seymour 2003). Models predict that the frogs should die at temperatures above 5ºC due to insufficient oxygen, but in reality, the frogs have an added advantage in the moss layers and rarely die at any of their natural temperatures (Mitchell 2002a). Not only does the moss permit aeration of both lower and upper surfaces, but the photosynthetic

oxygen production further supplements the oxygen available. At night it is safer for the frog to roam away from the protection of the moss. In the daytime, the nest of ***Crinia georgiana*** (Figure 60) in a moss bed had double the oxygen it had during pre-dawn hours (Seymour *et al*. 2000).

Figure 60. Two frogs of ***Crinia georgiana***, looking very much like two humans doing a dance! Photo by Jean-Marc Hero, with permission.

Byrne (2002) found ***Crinia georgiana*** (Figure 60) breeding in shallow temporary pools by a sloping, moss-covered granite outcrop where it "enjoys" the privilege of having a testes size at least four times that of any other species of ***Crinia***. This unusual size may be an adaptation to its habit of multiple matings (1-9) with a single female, creating sperm competition (Birkhead 1995; Byrne 2002).

Crinia tasmaniensis (Tasmanian Froglet, Myobatrachidae)

Crinia tasmaniensis, the **Tasmanian Froglet** (Figure 61), is endemic to Tasmania and must always be near water (ZipcodeZoo.com: ***Crinia tasmaniensis*** 2009). This requirement takes it to alpine areas, rainforests, bogs, swamps, fens, and peatlands, where mosses are part of its environment. Its call sounds like a bleating sheep.

Figure 61. The **Tasmanian Froglet**, ***Crinia tasmaniensis***, an inhabitant of bogs, swamps, and peatlands, among others. Photo through GNU Free Documentation License.

Geocrinia victoriana (Victoria Ground Froglet, Myobatrachidae)

Gollmann and Gollmann (1996) collected ***Geocrinia victoriana*** (Figure 62) in southwestern Victoria and from 180-1300 m in central Victoria from mosses in a roadside ditch and under grass tussocks. In laboratory experiments they demonstrated that populations from the mountains were larger when they hatched and grew faster than those from the lowland sites, but those from the southwest were similar to their counterparts at higher altitudes in central Victoria.

Figure 62. ***Geocrinia victoriana*** adult. Photo by Matt, through Creative Commons.

Summary

Although peatlands provide moist sites for adults to rest, bog ponds are often too acid. Acidification has resulted in extirpation of many species of frogs, interfering with development, but apparently the Wood Frog (***Lithobates sylvaticus***) is more tolerant and thus can inhabit low *p*H ponds without risk of predation by other amphibians. The tadpoles of the Green Frog (***Lithobates clamitans***) are apparently unsuccessful in surviving the low *p*H of bog ponds. ***Rana arvalis*** is one of the few species that is able to breed in acid peat bogs. Nevertheless, many frogs use peatlands in summer. Frogs such as ***Rana temporaria*** (European Common Frog) and ***Pelophylax*** spp. (green frogs) often make burrows in *Sphagnum* banks as a resting place in summer; other frogs may use those same burrows or tunnels and burrows made by small mammals. The ***Sphagnum*** Frog (***Philoria sphagnicolus***) male excavates a nest where the female deposits the eggs; the tadpoles remain in the nest. The destruction of peatlands can result in decreases in both numbers and diversity of anurans.

The **American Toad** (***Anaxyrus americanus***) is common in wetlands, including peatlands, as well as forests. Toads often spend the winter under bryophytes where both temperature and humidity are modulated. The bryophytes may be especially important during migrations. Some toads, such as tadpoles of the European common toad (***Bufo bufo***), may eat bryophytes, but it is possible these bryophyte fragments

come along with bacteria, algae, and other food items being scraped from their surfaces.

The Cloud Froglet Tadpoles (***Crinia*** spp.) require the moisture of mosses or lichens for the larvae to develop. The mosses also provide oxygen to the eggs and adults. Panamanian Golden Frogs (***Atelopus zeteki***) perch on mosses near waterfalls to maintain their moisture.

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