FROZEN FROGS — A NATURAL OCCURRENCE?

CHARLES A. SNELL

76 Birdbrook Road, Kidbrooke, London SE3 9QP

While making garden and vivarium alterations during the 1984-85 winter, I unearthed edible and tree frogs (*Rana esculenta* and *Hyla arborea* respectively) at a soil depth of 1-4 centimetres. While working in an outside vivarium (4 x 3 metres) I removed six tree frogs and one immature *Bombina orientalis* by placing them in a bucket containing about 15cm of soil and leaf mould and transferring this to a garden shed for one week until alterations were complete. During this period air temperatures hovered between —4°C and —14°C.

When the vivarium was ready to receive the frogs once more, I removed the bucket from the shed only to discover that soil, leaves and frogs were frozen rigid.

The frogs had a body surface temperature of —4°C. In this rigid condition no external respiration was possible and tissue respiration was presumably also at or near zero. I assumed these individuals had probably expired.

It then occurred to me that those individuals I had found in the garden 1-4 centimetres underground had also experienced similar or lower temperatures as the ground was frozen to a depth of 5cm. I reasoned that such ground freezing is a regular event in Central and Northern Europe where these creatures are naturally found. There seemed a good chance, therefore, that such total freezing was an occurrence the organisms could withstand, and would have to withstand in fact, in order to survive at all. For instance, I write this article from Sweden where tree and edible frogs and fire bellied toads (*B. bombina*) are native and where ground frost extends to some considerable depth (night temperatures here at the moment are between —10°C and —35°C). For Swedish herps to dig themselves in below the depth of ground frost is, in some places, impossible as the last glaciation removed much of the soil. In fact, some of the more barren rocky coastal areas and rocky offshore islands are the best places for herptiles. Natterjack and green toads (*Bufo calamita* and *B. viridis*) have, in fact, been found hibernating in crevices in rocks.

In spite of this reasoning the sight of my rigid, rock-hard specimens gave me great cause to doubt. They had even frozen with their eyes wide open, a most bizarre sight. I placed the frozen bucket and contents in the attic of the house which had an air temperature of +10°C and, after two days, reasoning won the day. Slowly on the afternoon of the second day five out of the six tree frogs had recovered all visible body functions and were even able to jump. The remaining tree frog and *Bombina orientalis* did not show loss or change of pigmentation normally associated with dead frogs and showed no signs of deterioration or decomposition. I could not continue observation as I had to return to Sweden and all were returned that same afternoon to a suitably sheltered spot in the vivarium where the air temperature had risen to +5°C.

This seems to reinforce many of my past observations. For example, as mentioned in a previous BHS "Bulletin" article, and at the illustrated talk I gave for the Society in 1984, survival from hibernation in the European tree frog seems greatest after severe winters than after mild or changeable ones. I suggested this may be because a lower metabolic rate makes less demands on fat reserves and the absence of large temperature fluctuations also might prevent the metabolic rate increasing too early in readiness to leave hibernation.

Some of my worst disasters in vivarium keeping have concerned my considering that certain of my amphibia or reptiles had not hibernated properly and then moving them "for their own good" with disastrous results.

Most of us become too anthropomorphic, or in this case "homoiothermically minded" when we consider the effect of cold on poikilotherms. We assume that they feel the same pain and discomforts as ourselves. It must be remembered that to us a drop in body temperature of 10°C would lead to great discomfort and eventual death if sustained, but is perfectly acceptable and even a regular occurrence, in cold-blooded creatures.

I recall reading in a great many biology books that homoiothermy (warm-bloodedness) is one of the great triumphs of evolution that has allowed homoiotherm (and of course this includes man!) to be independent of ambient temperatures and therefore to be more successful in the colder regions of the world. I would strongly question the complete accuracy of this. From where I stand in the world at the moment (central Sweden) one quickly reaches the opposite view. Snow has covered the ground and branches of trees since December. The mortality among insectivorous birds and herbivorous hares has been enormous. Most of their body fat has, of course, been used up simply in the effort of keeping warm while trying to exist at a time of the year when food is scarce. Even in milder Britain it has been estimated that well over half of the young of small insectivorous birds die in their first winter.

While all the suffering and death is going on above ground the amphibians and reptiles are below in a state of torpid oblivion but ready to emerge in the Spring hardly the worse for the experience! Another clear advantage related to cold-bloodedness is the ability to survive in situations where food is scarce. This, of course, is related to the fact that they do not "burn up" the calorific value of their prey in producing body heat. This being so a little bit of food goes a long way. In fact there are occasions where the biomass of amphibians can excede that of its prey species per unit area where the latter are faster breeding and/or growing.

To return again to frozen frogs, the northerly position of Sweden does not seem to have prevented colonization by amphibia. Common Frogs (*Rana temporaria*) are found even above the Arctic Circle. Sweden has six native frogs and five native toads (Britain has one native frog and two toads). These are the Common Frog (*Rana temporaria*), Agile Frog (*Rana dalmatina*), Moor Frog (*Rana arvalis*), Edible Frog (*R. esculenta*), Pool Frog (*Rana lessonae*), Tree Frog (*Hyla arborea*), Common Toad (*Bufo bufo*), Natterjack Toad (*Bufo calamita*), Green Toad (*Bufo viridis*), Fire Bellied Toad (*Bombina bombina*) and Spadefoot Toad (*Pelobates fuscus*). I have just read that ground frost this year in Sweden extends down one metre from the soil surface. If the amphibians were mortally affected by freezing one would expect almost a mass extinction of land hibernating species in Sweden (most of those mentioned above). It must be added that many of the species mentioned above are restricted to southern Sweden. There could be many reasons for this: i) some species could be more frost sensitive than others, ii) the length of the summer may be critical, iii) colonization of Sweden by herptiles has mainly been via Denmark in the South after the retreat of ice at the end of the last ice age, iv) Southern Sweden offers different habitats. Unlike the rocky, thin-soiled north with its predominating pine/birch tree cover, the south is flatter, deeper soiled and has more deciduous tree cover (including beech). Unfortunately, this flatter topography and deeper soil has made it popular for agriculture which has destroyed, and continues to destroy, habitats that favoured herptiles.

Of the foregoing I consider that ii) length of summer, may be the critical factor for many species, and that the main reason for this is the amount or duration of heat required to take an egg through to metamorphosis as a young frog or toad. This being true one would expect species that have the ability to overwinter as tadpoles to be able to extend further north. The green frog complex (*R. ridibunda/esculenta/lessenae*) have this ability and, in fact, the Edible Frog is found from south to central Sweden; the Pool Frog is concentrated in an area of central Sweden whilst the Marsh Frog has the strangest distribution of all. Absent from Sweden and mainland Denmark, it first appears in the Danish island of Bornholm in the Baltic, then reappears again in far more northerly Finland. I have found some amusement considering how they have found this island and reached Finland. The "Field Guide" by Arnold & Burton has a question mark for Marsh Frog in Finland. Scandinavian experts have since confirmed its presence. I consider it could have arrived by sea! I have found the Marsh Frog living and breeding on the Isle of Sheppey in Britain in quite salty water. In fact, in the dry summer of 1983 some pools were so brackish as to seem saltier than the sea as the waters had been condensed by evaporation. The surface waters of the Baltic sea are surprisingly non-salty. Far less salt, to the taste, in fact, than some brackish water used by the Marsh Frog. I was not aware of just how fresh the Baltic was until I watched some anglers last week (February 22nd, 1985). The majority of the Baltic was frozen over and the local anglers were taking advantage by boring holes in the ice and fishing with "spinners". Some anglers were doing very well and I was amazed to see that the main catch from the "sea" was freshwater pike and very large perch. To the taste, salt was hardly discernible. It is conceivable then that in cases of coastal salt marshes being flooded, washed out tadpoles could reach islands or other Baltic lands without loosing water osmotically to over-salty water and therefore dying.

The ability to overwinter at the tadpole stage must help to explain the success of the Midwife Toad (*Alytes obstetrians*) in Britain where it is found quite far north of its usual range (e.g. the colony in York).

The distribution of species which have tadpoles which do not have the ability to overwinter show differing trends in Sweden. The Common Frog, the Moor Frog (*Rana arvalis*), and the Common Toad (*B. bufo*) extend from southern Scandinavia to beyond the Arctic Circle. The climatic tolerance of tadpole and adult must be considerable in these wide-ranging species — certainly they have earlier spawning times than the following species. Both the Green Toad (*Bufo viridis*) and the Natterjack Toad (*Bufo calamita*) have more temperature sensitive eggs and larvae, and spawn later. Their range in Sweden does, in fact, follow the climatically optimal regions.

In conclusion, what I have been suggesting so far is that the Achilles heel for many species may not be winter cold but cool summers. This is an important distinction as most people I meet are surprised to discover that tree frogs can exist in Britain, adding "But aren't our winters too cold for them?". Forgetting, of course, that over a great part of its range in Europe it has to suffer much harsher winters. Britain, in fact, has mild winters because of the influence of the Gulf Stream. Unfortunately, this same factor can cause "mild" summers at a time when the reptiles and amphibians need heat most. And, therein, of course, lies one of the main disadvantages of cold-bloodedness at high latitudes.

Since writing this article (January '85), an article has appeared in the "New Scientist" relating to frogs surviving the winter. Apparently there are only four vertebrate species that are known to survive freezing and that these are all frogs. It confirms my observations that breathing and heartbeat are suspended and that the animals are literally "frozen stiff". Apparently they protect their body cells from frost damage by boosting blood glucose to 60 times its normal value, but only if during hibernation the hibernation temperature drops below freezing. I would like to know which species are included in the four. I have a suspicion that the tree frog and edible frog may not be, but clearly should be, included. In fact, most amphibians in northern temperate to sub-arctic regions (has anyone tested newts?) may have this capability.

This phenomenon was also well known to the Chinese for goldfish — these could be frozen solid and survive. I have, in fact, witnessed this minor miracle myself, having thawed out solid blocks of ice containing goldfish simply to witness their unbelievable recovery. I add this last aside as the authors of the article mention that only four species of vertebrate, and all of those frogs, are known to survive freezing.