Turtle Hibernation and Staying Under Water

Preface
In 2011 I wrote an article called Hibernation, Health and Habitat for Practical Reptile Keeping magazine. It was intended to help turtle keepers in the UK trying to keep temperate species under naturalistic conditions and to guide them through the overwintering process. The article was based on my experience and best knowledge at the time. In our hobby, knowledge concerning turtle hibernation of temperate climate animals was and is still in its infancy, so the article has been revisited often with updates. Some of which are recognised below.

- Donald C. Jackson (Professor Emeritus, Brown University) has contributed a considerable amount to our knowledge on turtle underwater capability. He and his students have produced many papers over time and data from which is well encapsulated in his book “Life in Shell” (Ref #1). Much of what is stated here comes from Jackson and his colleagues.

- Recently on searching the web I found an interesting presentation by Elizabeth Timpe (Ref #2) who has gathered together more facts that contribute to the picture of turtle hibernation and underwater sustainment of reptiles generally.

- Frances Baines is always provocative in the nicest way and for example her casual observation that neonates had no real bones has given much food for thought and has added to this dialogue.

A male Trachemys scripta just out, catching early spring sun on 23rd February 2012. Somerset, England.
Content
For the purpose of this discussion the word turtle is meant generically for all of the freshwater aquatic and semi aquatic chelonia – it’s the same as a terrapin. A tortoise remains a tortoise.

Over the years I have heard many definitions of the word hibernation and an attempt is made to set out its context for this note. The following sections then move on in small steps covering health then some of the physiological turtle/terrapin qualities and capabilities that contribute to a successful hibernation.

It is recognised that many species have differing overwintering strategies and a look at differing animal groups is taken. Feeding and habitat considerations are also touched upon with some suggestions of what could be offered in the UK.

Hibernation Definition
In his paper on hibernation in Horned lizards(1965), Wilber W. Mayhew noted in his abstract...

*The term brumation is proposed to indicate winter dormancy in ectothermic vertebrates that demonstrate physiological changes which are independent of body temperature......* it’s a term that has caught on and has been a cause for debate ever since. He has however also used the word hibernation in other of his papers.

The argument is better outlined in an article by the Obligate Scientist (Ref. #3)

Jackson in his book at (Ref #1) uses the word “hibernation” universally and that’s good enough for me.

Health
A successful hibernation has a prerequisite that the health of an animal is at 100%, so let's start with that:

Imported captive bred animals have never had to go through a natural selection process as they would in the wild. Contrary to popular opinion, breeders are meticulous with their breeding regime and a very high proportion of their hatchlings survive. Yet in the wild only a small percentage of all eggs laid turn into hatchlings as predation by raccoons, skunks and humans take its toll. Once hatched they then run the gauntlet with other predators, now including alligators, otters, fish, birds and of course humans. Any animal vaguely unfit is removed by nature; this is not the case in the turtle farms.

During rearing by turtle farms, the neonates will have been kept in clinical conditions with no contact with natural pathogens and with protection offered by anti-biotics and modern drugs and little natural immunity will have been developed. In a recent visit to a fish farm that breeds fish for the angling community I noted that breeding is initially conducted under the most stringent clinical conditions but then as the fry grow they are exposed gradually to pond water of increasing natural strength. The view at the farm was that if suddenly and directly exposed to the “wild” water mortality rates would be significant.

The young animals in nature have specific and balanced dietary needs along with the availability of natural sunlight and clean water. All too frequently newly acquired animals are kept and fed inadequately; the result is a weak animal or an animal that has grown unnaturally, often with a deformed shell. If its body or organs have not grown properly then it simply will not have all the tools to see it through hibernation as we shall see later.

I was fortunate enough to have visited Elmar Meier in Muenster Zoo and part of the discussion centred upon stress and the profound effect it had on the immune system; Kevin Eatwell at Edinburgh Vet School echoed him in another discussion. This part of husbandry gets too little attention but the reader should be in no doubt that a stressed animal is more susceptible to falling sick. Stress can be caused by physical health issues as well as
environmental issues and indeed psychological ones. When introduced into the “wild” of an outdoor pond a number of stress factors will kick in which may manifest in serious illness of one form or another.

- In a totally new environment, for some species it can take months to settle down and so the animal may not come to condition in time for hibernation.
- It will probably be colder than the indoor tank so appetite will be depressed.
- The feeding regime will be different so intake will be reduced
- The indoor photoperiod may well be different to that outside and animals can take a while to get used to the new daylight hours.
- I had an animal that took two years to get used to the space having been cooped up in a small box. He was too scared to come out and eat!

**Hibernation Discussion**

A turtle’s capability to survive under water for periods of time including months of hibernation is just fantastic and its worth having a look at some of the tools they have for doing that.

1) Turtles and some other reptiles have a lung capacity up to 10 times greater when compared to mammals, so can hold more air/oxygen. They also have less than 10% of our metabolic rate, so they use less oxygen. This means that their capacity to sustain themselves with air carried oxygen can be 100 times that of a warm blooded animal. In addition they don’t have to cope with the regular breathing like us warm bloods’ in order to keep us warm. They only breathe when they have to (Ref. #2); in cold water when they are torpid with low metabolic rates their need for oxygen is massively reduced. Jackson once thought whilst testing cold water survival that his subject was dead because the heart beat monitor showed nothing; however, to his surprise, after 10 minutes, he saw a movement on his test equipment indicating life. Blood is pumped sparingly, just enough to keep the brain alive. (Ref. #1).

2) Turtles have a liver that forms about 4% of body mass, this along with body fluids and muscle tissue store huge quantities of glycogen which is used as an energy reserve for the winter. It’s commonly thought that fat is the main energy store but fat cannot be metabolised without oxygen (Ref. #1) ie in anoxic conditions. However fat is stored and can be used when oxygen is available.

3) Turtles have other adaptations, in his book Jackson (Ref. #1) talks about the turtle heart having an extra valve with a capability to divert unwanted blood flow away from the lungs once lung oxygen is depleted. He also talks about management of acidosis in anoxic conditions and the buffering and sequestration of lactic acid (more later). Under such circumstances I would describe the wintering state as full hibernation. Tortoises have a similar physiology to turtles and will have similar capabilities.

4) Most turtles are good at extra-pulmonary (without use of lungs) oxygen uptake and it is commonly thought that the principal method of oxygen exchange is via the cloacal (vent) and/or buccopharyngeal (throat) pumping. Diffusion through the skin is also a most significant oxygen supply mechanism for the species of turtle we are most likely to encounter (Ref. #1). Jackson has proposed with some experimental evidence that under the lowest metabolic rates, water exchange in the cloaca does not happen but that the majority of oxygen uptake is through the skin and is enough to sustain the animal in water that has good oxygen content. Upon reflection this makes sense as to pump water through the cloaca takes energy and for the longer winter durations every scrap of energy must be saved. It does seem that nature has evolved the most effective and appropriate way for our turtle to gain extra-pulmonary oxygen that varies with species, size, sex, age, climate, oxygen levels and temperature.
Some statistics for extra-pulmonary uptake show the variation out there. Please note that some of these animals do not hibernate so their extra-pulmonary strategy exists for extending their time under water and may be energy consuming. (Ref. #1 and Ref. #2)

i. *Elseya latisternum*  
49% Buccopharyngeal cavity  
33% Cloacal bursae  
18% skin

ii. *Podocnemys*  
90% Cloacal bursae

iii. *Sternotherus*  
30% Buccopharyngeal cavity  
70% skin

iv. *Chrysemys and Trachemys*  
100% skin

5) Jackson has shown that with lower water temperatures, less energy is consumed, thus less oxygen is required. This is important for the keeper to understand as there is a significant difference of energy usage between $10^0c$ and $3^0c$. This is especially important for the pond dwellers, it will be remembered that up the American north, winters can last many months so that any energy saved can be reserved for the first days of spring. In addition, in anoxic conditions, glycogen is used significantly faster so lactic acid is produced in greater quantities. Stories are often told about turtles moving about under the ice, now we have a reason. As I write this in December my hibernating Painted Turtles (*Chrysemys picta*) and *Emys orbicularis* are moving about the bottom with water at $6^c$.

6) With deep still water, anoxic layers can form in the pond. This can happen when bacteria oxidise detritus in the pond using oxygen at a greater rate than plants and nature can replace. The detritus also generates other dangerous gases such as hydrogen sulphide. This can happen in the summer as well but is not a problem as turtles then have a higher metabolic level enabling an easy swim to the surface for oxygen. In winter when ice forms it prevents surface gas exchange and matters are made worse when snow settles, as it stops the light getting to the plants, thus they stop producing oxygen by photosynthesis but they continue to use it for respiration. Very quickly the water is depleted of oxygen and becomes anoxic.

7) The effects of oxygen deprivation are similar with turtles and humans but of course turtles have potentially 100 times our resistance to hypoxia. Lack of oxygen or glycogen impairs brain activity significantly that's why pilots need oxygen masks at high altitudes. The burn of glycogen without oxygen forms lactic acid in the blood. In marathon runners this contributes to seizing up the muscles and is called acidosis, the same will kill a turtle in extreme cases. It can be seen that if a riverine turtle is caught in an anoxic pond as a result of freezing and is unable to get to the surface air easily, it is seriously at risk. This happens in the wild surprisingly often.

8) Many turtles, in particular the pond turtles, have the ability to utilise the calcium carbonate (CaCO$_3$) within the shell. Their shell is about 40% of body mass and its calcium is used to buffer the lactic acid in the blood and raise the pH thus reducing the effect of acidosis (Ref. #1, Ref#5). In addition the shell can sequester some of the lactic acid and store it for disposal when oxygen becomes available again after the winter thaw.

9) The build up of lactic acid can take days or weeks depending on the temperature and oxygen levels in the water. The lactic acid in the blood and in the shell can take equally long to dispose of once conditions are
Hibernation #11  
November 8, 2014

better in spring. The calcium used must also be replaced, so for females about to produce eggs this is a particularly hard time.

10) Upon rereading (Ref. #1 and Ref. #5). work and the works of others, it is clear that the age (and maybe the sex of animals) also has a part to play in the overwintering strategy. The skin surface to animal volume ratio plays a part here and the same law applies to the capability of storing/ buffering lactic acid.

- Males of some species such as the Maps are considerably smaller than the females thus their skin area to volume ratio is better, so offering a better extra-pulmonary capacity.

- A larger animal will have a larger shell thus potentially an improved capacity for Lactic acid buffering and sequestration.

- Reese (Ref. #5) confirms that some youngsters are less capable of overwintering than adults; this is due to a combination of the above factors. It may also be a reason why in the first year overwintering sometimes occurs in the nest site. A newly hatched animal will have reduced bone structure and hence no available carbonate buffer for anoxic conditions (remembered that hatchlings come with a cartilage structure that ossifies as the animal grows). Many breeders keep their hatchling indoors over the first few winters, here’s a good reason for doing so.

- The paper on hibernation of hatchling turtles by Patrick J. Parker et al (Ref#11) discusses the ability of species to survive freezing temperatures and that the nature of the substrate also plays a part both in temperature management and hydration management.

- As a contrasting thought I have spoken to keepers that have expressed the idea that some species need to go through the hibernation process as youngsters and have their innate body habits accustomed to the changing seasons. Rogner (Ref #14) states that in practice he overwinters his yearling Emys indoors with some success.

**Hibernation - Other Considerations for the UK**

As UK keepers we must also remember that many tropical and subtropical turtle species have not evolved to survive colder temperatures and do not utilise hard hibernation as an overwintering strategy. In the cooler weather they just drift in and out of torpidity. There are also those marginal, temperate climate species that may be particularly challenged by the insipid British springs. This would include animals from say Indiana/Kentucky/Virginia southwards or parts of China and parts of the Middle East.

Over the years I have kept many American species outside and it seems that in my ponds that the Sliders do much less well than the River Cooters, the Spotted, the Painted, the EuropeanEmys and the Common Map turtles. Initially I thought it might just be the anoxia capability as many other keepers with a high flow water filter system seem to do well. Now some 12 years plus into keeping turtles outside I am concluding that the Trachemys group really struggle in the British climate. Those that survive probably have a genetic background that originates from the northerly states.

Jackson indicates that northern variants of some species may have better overwintering capabilities than their southern cousins (Ref#1). A vital consideration therefore for those of us wanting to keep turtles outside in the UK is confirmation that the species is at least suitable and that its genetic source is of a northern nature.

The turtles commonly available in the UK are mostly from North America and can be split into two groups for the purpose of this discussion.
Those that are riverine species and those that are enclosed pond dwellers.

- **The riverine species** hibernate in rivers with a frozen surface but the water continues to flow and is generally rich in dissolved oxygen throughout the year. In this group belong the Sliders (Trachemys sp.), the Cooters (Pseudemys sp.), the Map turtles (Graptemys sp.), the soft-shell turtles (Apalone sp.), and Musk turtles (Sternotherus sp.). These animals often have good skin surface compared to their volume as well as cloacal (vent) and/or buccopharyngeal (throat) strategies. The prerequisite requirement for this group is well oxygenated water for overwintering.

- **Enclosed Pond Dwellers** predominately inhabit ponds that have no great moving water source and that get totally frozen over/in, in the winter and have potential for becoming anoxic. The Pond dwellers include the Painted turtles (Chrysemys sp.), the Snapper (Chelydra sp.) and the Spotted turtle (Clemmys sp.). I believe that the European Emys falls into this group but have found no supporting evidence, I have just my experience for the assertion. This group seeks out the coldest water in order to reduce their metabolic rate in preference to higher oxygen levels.

It’s an interesting thing that riverine species are particularly adept at extra-pulmonary oxygen intake but cannot cope well with water that is depleted of oxygen. A Slider can survive in anoxic water no more than about 10 days, Cooters are a bit better so it varies from species to species. However the Painted turtles can survive 150 days in anoxic water (Ref#1).

**Feeding**

I was always under the impression that turtles were unable to eat until the water temperatures reached about 15°C. Last year the turtles that were in the greenhouse came out of hibernation early because of the warmer air temperatures, as they were moving about I thought I might try feeding them a meal worm. 7th February is recorded in my diary and although water was below 10°C; air temps did reach 29°C. What surprised me was that all of them ate well! If the animals are sunbathing and getting their body temperature up, trying some food no matter how cold it is outside, is worth doing. It takes away their reliance on their glycogen stores.

**Daylight**

For some while the triggers for hibernation have been monitored and whilst animals will eat at low temperatures in the spring my animals have gone off their food by October despite the water still being warm. Monitoring barometric pressures seems to show no correlation. The driver for hibernation, it seems is the recognizable reduction in daylight length around the equinox and the lower temperatures that come with it.

**Habitat**

Read any of David Carrol’s books (Ref. #13) - his accounts of turtle migration as the seasons change are very telling. He talks of migration in spring to vernal ponds where there is plenty of easy food such as tadpoles. He talks of migration to breeding areas and of migration to other areas as food availability changes. In the wild they have to hunt for their food and learn where to find it with the seasons. Their willingness to travel and explore will be an issue so the garden must be secure as they are great climbers. It is noticeable in my naturalistic set-up that the many animals become more willing to get out of the pond and go hiking – presumably it is the instinct to travel to hibernacula.

The wild turtle may well have an internal map for the best hibernation location, sometimes this may be communal. When winter comes, pet turtles will not have a choice of location for their big sleep and the pond keeper must provide suitable hibernation conditions appropriate to the animal type kept. Most people keeping turtles in ponds in the UK will have the riverine type of turtle implying a need for well oxygenated water.
Matters are complicated because books are often out of date and only hint at real hibernation needs. My Spotted turtles (Clemys guttata) and European Pondies (Emys orbicularis) are known to be more terrestrial but all literature talks of their hibernation in water. Yet I have had animals that have hibernated on land, the extent of this habit has varied with animal and with the weather. Even as I write I have a male Spotted turtle (Clemys guttata) that spends the night under leaves and if it is nice he comes out, after a few days if he is dehydrated he dips in the water then becomes a land animal again. Similarly, writers only hint that the Wood turtle (Glyptemys insculpta) prefers river waters – mine will sit in the pond waterfall enjoying the cold well oxygenated water stream. Where they have been given an option I have found that some 50% of my animals (Clemys and Glyptemys) have hibernated above water.

From my understanding the riverine animals will take care that they have good oxygenated water if it is available to them but in the wild they will also have to deal with water level changes. In the UK winter, we think floods, however in northern USA the depth of winter brings months of freezing temps often less than -10°C for weeks and weeks. Rain does not fall; snow does, several feet in fact. This snow acts as an insulator from the severe weather above the water and ice layer. The temperatures in the water will be the same as we would find in the UK. During the winter period the water levels often drop and air gaps develop between water and ice, animals will take the opportunity to use airborne oxygen rather than water borne oxygen simply because it is more efficient in using energy resources. I have seen my animals sitting (hidden) near the surface and gently poke their noses to get air.

Winter of 2011 was a nightmare for many of us in the UK that hibernated turtles outside. Whilst my pond dwellers all did well generally, my riverine species were hit very hard. The ice stayed for nearly a month and as I don’t have any pump system the inevitable anoxic conditions overcame some of my animals - mostly the big Slider females.

So finally the habitat too, plays a part in the ability for the turtles to survive outside in the UK.

**So what do they need in UK outdoor situations?**

As outlined above, turtles have many complex needs and just placing them in a pond does not mean it will be suitable. It is, unfortunately, an assumption commonly made.

Turtles are ectothermic and need heat from sunlight to raise their metabolic level in order to move and digest food. This temperature varies from animal to animal but 35 – 40°C is a good generality and in a sheltered spot that temperature is easily achieved even in the UK. They need sunlight providing ultra-violet A and B to help manage a number of important biological functions including the production of vitamin D3, so vital in replacement of used calcium and in preparation for egg laying; sunlight UV also acts as a bactericide- so valuable to deal with post hibernation such as fungal growth or sticky eyes. These two sunlight qualities (heat and UV) go hand in hand. Without sunlight they will simply not survive. Their pond therefore needs a basking area that has full sunlight for good parts of the day but especially around midday. The basking area should be private so they are not scared into the water frequently and a wind shelter will help too.

They should be able to get into their basking area easily. In discussions with other keepers it seems to me that those that have a filter with a waterfall output are generally successful with keeping Sliders and this may also apply for the Maps and Cooters.

The animals that I have had good success with are Painted turtles (Chrysemys) – all 4 subspecies, Spotted turtles (Clemmys Guttata), Cooters and River Cooters (Pseudemys floridana and concinna), False Map turtles (Gramptemys pseudogeographica) and of course our European Emys orbicularis.
The pond should not be too deep, say less than 2 feet. This depth allows sunlight to penetrate allowing plant oxygen generation. It also helps to reduce build up of anoxic water layers by water circulation due to wind.

The pond should have sloping sides so that animals can move about and get to the surface easily if they are cold stiff or in trouble through acidosis.

The pond should have as many oxygenating plants as possible. If snow falls, clear it off the ice above the plants and allow the sunlight back in.

All the species emerge within a week of each other. 21\textsuperscript{st} March 2010. Somerset England

**In conclusion**

There is no doubt that many of the commonly imported American turtles from the Northern States can survive in outdoor ponds in the UK. This is confirmed by the many thousands that have survived since the original Ninja craze over 20 years ago. The most commonly released – the Sliders and the Cooters - are often from the warmer parts of the USA and may not be genetically disposed to the long winters and the cool summers here in the UK and their mortality rate is high. Those that survive are a credit to Darwin and are probably from northern stock.

If an animal is healthy, is lucky with its genetic makeup and is provided with suitable conditions it will survive many outdoor years in the UK. I have animals that have been outside for over 15 years.

**References**

If you want to read more get these two books first, both are excellent with good technical information that a non-scientist can understand.

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A note of thanks
Paul Eversfield and Frances Baines were both very generous with their time and advice over the years and I just need to record how much it was valued.

Author


I am happy for this paper to be used for the purposes of enhancing the hobby but I keep copyright. More data will emerge adding to the story or I may have got it wrong, it will continue to evolve.