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Glyptemys muhlenbergii (SCHOEPPF, 1801): 40 Years of Experience with Keeping and Breeding compared to its Life in the Wild

Summary

It is by now for more than 40 years that I have been keeping a male of *Glyptemys muhlenbergii* and three females for more than 34 years in Graz, Austria; referred to in the following as my founder animals. Aside from portraying the experiences I have made during this time I also want to use this contribution to find answers to the question as to how far the life of turtles under long-term husbandry conditions comes close to that of their conspecifics in nature, and how the insights obtained

thus can be used to complement our knowledge of their natural history. If the outcome were altogether positive it would not only strengthen the justification of keeping wild animals in human care, but also provide a good basis for possibly necessary re-introduction projects.

It is against this background that I will in the following juxtapose in opposition the ontogenetic development of this species, its growth, ethology, fertility data, oviposition, hatching rates, and the raising of juveniles in my care to corresponding observations in nature.

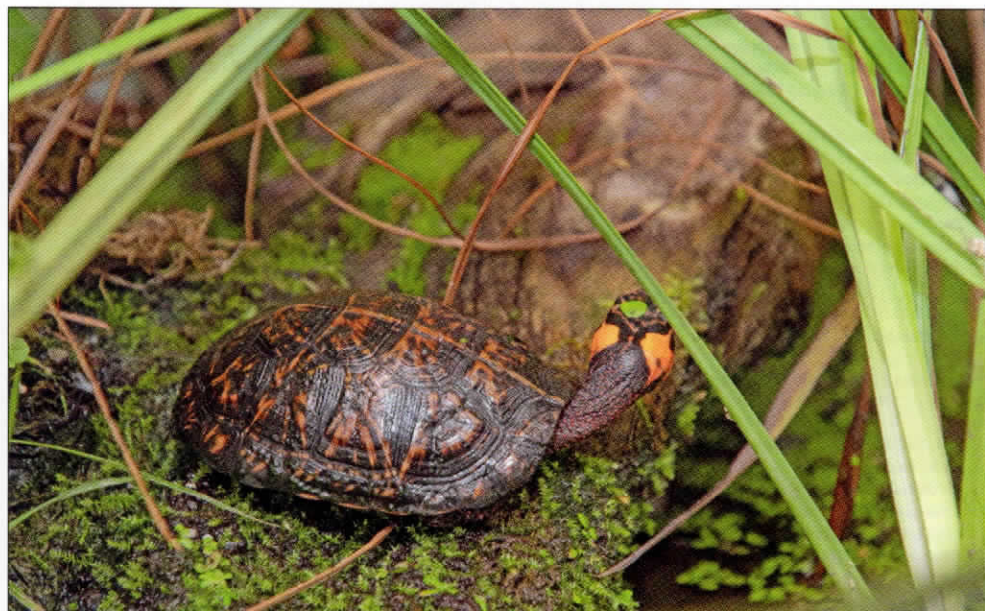


Fig. 1: The most obvious feature of *G. muhlenbergii* is the presence of a large, yellow to reddish spot on either side of the head. These spots are more or less widely separated when viewed from above. Photo: F. GRASSL

The following information on the husbandry conditions for my *G. muhlenbergii* is based upon my personal experiences from the past forty years in a comparative overview with the results of the intense field studies on this species. These were likewise obtained for the past forty years by my US-American friend and colleague R. ZAPPALORTI of Herpetological Associates, a consulting firm for environmental matters (publications and personal communications in writing and verbally).

Results

The four founder specimens in my care mentioned above developed similarly as to body shape, size, colour pattern, and signs of ageing etc. compared to specimens in the wild.

The young produced in my care grew a little faster during their first years of life, but largely compare to those in nature with regard to shape, size and appearance.

The numbers of clutches and eggs produced by my founder animals conform to those in nature.

The females from my own production produced their first clutches in one instance at an age of 5 years, while others began reproducing unusually late in life at ages of 8, 9, 13, and even as late as at 16 years.

Their numbers of clutches per annum match those in the wild, but the numbers of eggs per clutch do not! My captive-bred specimens produced significantly more eggs already during their first years of reproductive activity.

Noteworthy, and inexplicably, is that my first three captive-bred females died of egg-binding following 8–15 years of laying eggs without problems.

My attempt at an explanation

I have largely managed to emulate in my captive setup the natural habitat, territory, and climate in the natural distribution range of this species. The most major difference compared to my husbandry conditions I find in the fact that these animals have a qualitatively more

diverse, yet quantitatively reduced availability of food in nature.

For the first 20 years of my keeping this species I had only one male (Spec. 1) available for breeding purposes. As to how far a larger number of males might impact on the reproductive output of a female in the wild is something I dare not speculate about.

Original description, description, conservation

Gotthilf Heinrich Ernst MÜHLENBERG (1753–1815) was an US-American, Lutheran theologian and naturalist whose systematic studies earned him the by-name “the American Linné”. According to Wikipedia, he discovered the Bog Turtle in Pennsylvania, collected a few specimens, and made these available to his friend, Johann David SCHÖPFF; the latter then described it as a species in 1801 and named it *Clemmys muhlenbergii* in his honour (SCHOEPPF 1801). HOLMANN & FRITZ (2001) eventually placed this taxon together with the former *Clemmys insculpta* in the genus *Glyptemys*, which was a move rejected by ERNST (2001).

With its small adult carapace length of rarely more than 100 mm, it ranks amongst the smallest turtle species in the world and, possibly aided by its secretive ways of life in marshy areas (which explains their common name, Bog Turtle), it has always been regarded as rare (EGLIS 1967). A tell-tale morphological feature is the presence of a yellow, orange or orange-red spot behind the eye that may almost fuse on the crown with its counterpart on the other side of the head and expand down as far as onto the throat (Fig. 1). These spots may, however, also be fragmented or, usually in old specimens, be all but missing. Males grow a little larger than females, with the size record being 123 mm in CL, and as far as I know, only one female has ever been found whose shell length exceeded 100 mm. RYAN (1981) reported on receiving a female in Lebanon County, Pennsylvania, in 1971 that

measured a record carapace length of 105.8 mm and produced a clutch of six fertile eggs in the same year.

This species initially featured informally in the appendices of CITES from 1973, and was placed on Appendix II right during the first official Conference of the Parties (CITES 1976). The year 1992 then saw it being upgraded to Appendix I (CITES 1992). In the US, it has been classified as a threatened species since 1997 and is “federally protected”, which is the highest national protection status. The IUCN classifies it as “CR”, i.e., critically endangered and threatened with extinction (VAN DIJK 2011).

Glyptemys muhlenbergii as an object of ethological research

In nature:

„Of all the turtles known to occur in the United States none has remained more exclusive and poorly understood than the Bog Turtle. It is truly one of the rarest and most mysterious chelonians...” (ZAPPALORTI 1976).

Various researchers have over the last fifty years dedicated themselves to the study of this species in nature.

One example: R. ZAPPALORTI has been dealing with *G. muhlenbergii* since 1972. From 1975 through 1977, he conducted behavioural studies under commission from the Staten Island Zoo and the National Audubon Society. Between 1978 and 2002, his studies on Bog Turtles were funded by the New Jersey Division of the Fish and Wildlife Service and The Nature Conservancy by means of various contracts. Support also came from the owners of private lands, especially in Sussex County in the north of New Jersey, who allowed him to access various bogs for the purpose of studying these turtles.

Visiting these habitats at weekly intervals, he marked a total of 97 specimens, of which 51 were subsequently found again once to nineteen times, so that their exact locations, types of activity, dimensions, weights, tem-

peratures, body conditions etc. could be assessed and kept records of in lists. It was thanks to the kind recommendation of the late E. HOFMANN that I was able to accompany ZAPPALORTI on one of his bog excursions in early May of 1980.

I have to point out here that field studies of this kind typically produce momentary snapshots quite like a photograph that will likewise not depict what happened a few minutes later and hardly facilitate conclusions on the behaviour of an animal. This applies in particular when a specimen is picked up for examination and flees right after it has been released. Animals as small as these turtles depend for their survival, aside from mimicry and camouflage, largely on their escape skills. When we explored the edge of a marsh for the presence of Bog Turtles in 1980, we came upon a specimen that was basking in water just 1–2 cm deep above the muddy bottom so that only the top of its dorsal shell extended from the water surface. On our approaching it to about 5 metres, the turtle lowered its anterior body, made some swimming motions in a downward direction, submerged itself in the mud, and then shook itself in the manner more commonly known from snakes, lizards and soft-shelled turtles. It took only moments for it to have disappeared; it had obviously considered us a danger.

In zoological exhibitions:

About ten zoos in the US and southern Canada have permits issued by the US Fish and Wildlife Service to keep *G. muhlenbergii* for research purposes and they have been propagating them for years. Owing to its small size and secretive habits, it does not have great value as a display animal, and due to this and its likely vulnerability to theft I almost always found Bog Turtles hidden in backstage chambers away from the eyes of regular visitors. Accommodated in adequately large and structured enclosures they would in any case be seen only rarely.

In private collections:

In human care, these turtles tend to perceive their “care personnel” as no threat to them after only a short while. This applies even more to when they are kept in colonies, in which a shy specimen would always come up short during feeding sessions. They instead learn to associate the appearance of a human with positive experiences, which is life-altering change in perception compared to nature!

Captive settings afford the keeper greatly improved possibilities for making observations as compared to the wild. I have, for example, installed seats next to several of my turtle enclosures where I can sit down and my existence will soon be forgotten by the turtles. Working or just sitting there reading allows me to glance at my animals occasionally or have my attention drawn to sudden activities. My observations therefore do not match a photograph, but rather an extended motion picture sequence from which I can “edit out” less interesting periods of resting, sleeping or basking. What is left after hours, days and years will add up to an incredibly large sum of behavioural data that will be far greater than what can be obtained from sporadic field trips. However, this also raises the question as to how far we can draw conclusions from the behaviour of these animals in our enclosures that can be extrapolated on that of free-ranging conspecifics.

Along these lines, Konrad LORENZ (1978) had the following to say [in transl.]: “The lowering of general excitability under constant and therefore trigger-deficient conditions alone is enough to imply that unspecific triggers and their alternation are required to maintain a normal degree of excitability... The lowering of the general excitability is an effect that can hardly be avoided when higher-class lifeforms are kept captive. Because such will not only strongly impact on nervous functions, but also on the metabolism, it represents one of the most

important causes of disease in captive-kept animals” K. LORENZ furthermore thought that one of the most common pathological disturbances in the behaviour of captive-kept animals was a decrease in the intensity of an activity; like when a nest (in birds or reptiles) is left incomplete. On the other hand, he pointed out, that the influences of captivity had merely a reducing effect on behavioural patterns.

K. LORENZ went on to state: “If only to know whether a behavioural expression corresponds to species-specific behaviour in nature or is pathological, the observer has to be intimately familiar with the species under study. Knowing an animal as a means of researching it entails that you develop a certain degree of clinical view that can come only from long years of experience.”

G. muhlenbergii was exported to Europe already around the end of the 19th century and so found its way into some private collections (VON FISCHER 1884, KREFFT 1905). The life expectancy of these rare novelties was said to be only a few weeks, though. Today, this species is hardly seen in private hands due to its national and international protection status.

Natural habitat

Occurrence, geographic distribution

The natural distribution range of *G. muhlenbergii* is still incompletely known due to its small adult size and secretive lifestyle, and it is just to say that our knowledge in this regard is subject to continuous change. New colonies are continued to be discovered to this day, while some long-known ones have to be reclassified as extinct. In the widest of senses, this species occurs from western Massachusetts and western Connecticut via southeastern New York, eastern Pennsylvania and New Jersey, to northern Delaware and northern Maryland. Isolated populations are known from northwestern New York, northwestern Pennsylvania, southern

Virginia, western North Carolina, northern Georgia, and eastern Tennessee. According to B. TRYON (verbal comm. 1996), who kept an eye on the populations in northwestern Pennsylvania, no specimens have been seen there for quite some time. It has apparently also disappeared from Staten Island by now.

Population densities, threats

Muhlenberg's Bog Turtle commonly lives in small colonies whose densities are determined by the intraspecific aggressiveness of these turtles, their species-specific requirements to their environment, the availability of food, and the degree of human disturbance. The average number of individuals in a colony amounts to 20–50 specimens, with headcounts exceeding 100 being very rare.

The main reasons for the dramatic decline of the populations are sarcastically termed "land development" in the US, which means the draining of wetlands for erecting buildings, establishing road infrastructure, and creating new farm land, or merely the compromising of water quality from over-fertilization, the use of thawing salt on the roads, or the filling or closing-off of feeder streams to marshlands.

It is therefore all the more pleasing to see that measures for saving the natural habitats of this turtle species have found sponsors and were commissioned, for example to acquire previously privately owned land. One such example is the purchase of 131 acres (a little more than 50 hectares) of an intact marsh in New York state in which the conservation management and the overseeing of scientific research was entrusted to J. HERMES and J. BEHLER (ANDERSON & BEHLER 1984). As another conservation measure was established the removal of specimens threatened by scheduled building activities on private properties, for example, for release in suitable replacement habitats. This in particular requires detailed knowledge of the ecological requirements of this animal species.

Climate

In nature:

The climate in the natural distribution range of *G. muhlenbergii* reaches its highest temperature peaks in summer (Philadelphia 29.9°C, max. 40°C) and its lowest in winter (Philadelphia -4.2°C, min. -20°C). Due to marsh plants that will stand tall in summer and the slow yet constant flow of water, water temperatures in the marshes will hardly ever surpass 25°C during this period. The slow current, on the other hand, will also prevent the formation of thick ice in winter other than for brief periods with very frosty days. Precipitation is almost evenly distributed across the entire year, with slight peaks in summer. Humidity values range very high at night and on days without sun in the marshes. A vital factor for the turtles is that the hours of sunshine increase from 4.3 hours in January to 9 hours in June. This species inhabits only those marshes that are not shaded by trees and where the water surface will therefore be fully exposed to solar irradiation when the reeds are still low in spring. If females deposit their eggs in spots that will in the subsequent growth phase of vegetation become shaded, these eggs might fail to develop as a result of incubation temperatures being too low (ZAPALORTI *et al.* 2017).

In my care:

My enclosures for *G. muhlenbergii* are set up in glass houses and are without exception illuminated by daylight. By trimming the surrounding vegetation more or less I control the degree of their exposure to natural sunlight in accordance with the seasons. This measure together with a deep layer of bottom mud enables me to prevent the shallow areas of water from overheating in summer and freezing in winter. In total, this setup largely emulates the most important climatic factors, such as air and water temperatures, relative humidity, quality of light, and duration of insolation, of the natural habitats in New Jersey for instance, in Graz, Austria.

Variability of natural habitats, territory

In nature:

The English common name, Bog Turtle, already points out the type of wet natural habitat this turtle lives in. It occurs preferably in *Sphagnum* marshes that are fed by small streams or directly or indirectly by underground springs. Moreover, low water levels of less than 20 cm and a specific flora are characteristics of suitable habitats. BARTON & PRICE (1955) provided a rather good characterisation of this species in that they wrote that their highly domed carapace would often be dry and their feet usually wet. In Maryland, Bog Turtle habitats may also be located in forested areas, whereas these will typically be situated in open grass savannas in New Jersey and Pennsylvania. Marshes this shallow are obviously very sensitive by nature and subject to continuous change from drying up, silting up, flooding, overheating and damage cause by storms.

Sizes of marshes inhabited by Bog Turtle colonies vary from about 1,000 to 300,000 m². Males occupy territories of some 1,760 to 13,300 m², and females live in smaller ones of 660 to 12,600 m². CHASE *et al.* (1989) noted that individual territories may overlap.

In my care:

SACHSSE (1974) at the time kept *G. muhlenbergii* in a space-saving two-storey aquaterrarium in his apartment. While it was a remarkably clever and well-conceived way of keeping, it cannot unfortunately be adapted to my subjective idea of recreating the appearance of a secondary natural scenery in my care.

When I was planning my house in Graz in 1985, I set myself the goal of incorporating a setup that would be suitable for keeping together a small colony of one male and up to three females of *G. muhlenbergii*. It was not only to cater for the natural requirements



Fig. 2: A view into my 5.7 m² enclosure, from the terrestrial to the aquatic section. Here, the turtles will bask in the morning hours, and even though the sun does not reach and warm this spot in the afternoon it is here where the females will deposit their eggs in the evening in late May almost without exception.



Fig. 3:
In the wild of
northern New
Jersey: a Bog
Turtle leaves
its night shelter
in the morning
to take in the
warmth of sun-
shine.



Fig. 4:
A natural habitat
of *Glyptemys
muhlenbergii* in
northern New
Jersey.



Fig. 5:
R. ZAPPALORTI
having some
difficulty to
move through the
marshy terrain.

of these turtles as well as was possible, but also to create a basis for living with them. I therefore designed a "Sphagnum bog", which could be looked into from three sides from the living room and was facing south. I reserved 5.7 m² for this installation of which about 3 m² were to be filled with water, the latter of which I constructed DIY in the shape of an Eternit panelled tub 25 cm in depth (Fig. 2).

Plants, bottom substrate, other structures In nature:

Inhabited habitats are marked also by the presence of clumps of a wide variety of marsh plants emerging from the water at least along the edges. These clusters of marsh grasses provide the small turtles with cover and support for resting, spending the night, and hibernating both above and below the water surface. Some 5–10 cm above the waterline, they are used for basking and oviposition. *G. muhlenbergii* excavate tunnel systems in these grass tufts and *Sphagnum* cushions that will run partly above and partly below the waterline. Their walls are reinforced with rotting plant matter and compacted mud, which obviously maintain a very high level of humidity. Conditions like this make up the elementary microhabitat of these "moles of the marshes" (Fig. 3).

When I was first able to participate as a guest in one of the field excursions conducted by R. ZAPPALORTI in northern New Jersey in early May of 1980, I was able to identify from my previous studies of the literature the right kind of habitat already from afar (Fig. 4). As we approached the marsh in a depression of the land it did not take long before we were walking in soaked boots. We then had to hop from one cluster of grass to the next in order to not sink into the mud between these (Fig. 5). The surrounding vegetation was still very low, and it was only dry reeds from the previous year that stood about a metre tall here. These stalks shed dozens of ticks on me when I carefully navigated through them.

Predominant in this vegetation were peat mosses (*Sphagnum* spp.), reeds (*Carex* spp.), sweet bay magnolia (*Magnolia virginiana*), marsh elders (*Alnus* spp.), red maple (*Acer rubrum*), swamp honeysuckle (*Rhododendron viscosum*), various marsh berries, willow (*Salix* sp.), marsh orchids (*Arethusa* spp. and *Pogonia* spp.), water lilies (*Nymphaea* spp.), common cattail (*Typha latifolia*), sweet flag (*Acorus calamus*), common rush (*Juncus effusus*), hairgrasses (*Eleocharis* spp.), bulrushes (*Scirpus* spp.), cutgrass (*Leersia oryzoides*), false nutsedge (*Cyperus strigosus*), and an assortment of ferns. The ground of these marshes is mainly muddy, rarely firm or even rocky.



Fig. 6:
The embankment
zone in my large
pen sports muddy
ground, just as in
the wild.

In my care:

The subadult and adult *G. muhlenbergii* in my care have the benefit of a muddy bottom some 10–15 cm deep in the aquatic sections of the larger pens that are furthermore outfitted with native marsh plants such as rushes, irises and marsh grasses. The expanding networks of roots of the latter over time create a more or less solidified bottom substrate in which the turtles can establish their tunnel systems, just as they would in the wild. Buckwheats, duckweeds and cushions of *Sphagnum* in the embankment zones of the ponds create a naturalistic impression (Fig. 6). I have never effected a complete exchange of the pond water in more than 30 years of operation. A feeder pipe from the roof channels rainwater into the ponds, and an overflow limits the maximum water level. Guided by nature, I leave the marsh plants to grow taller after the oviposition season from June so that they may keep more of the summer sun from reaching the water surface.

Competitors for food, predators

In nature:

The preferred natural habitats of *G. muhlenbergii* are home to other chelonian species as well. Competitors for food in these shallow marshes are limited to small Common Snapping Turtles (*Chelydra serpentina*), Painted Turtles (*Chrysemys p. picta*), Common Mud Turtles (*Kinosternon s. subrubrum*), Common Musk Turtles (*Sternotherus odoratus*), and Spotted Turtles (*Clemmys guttata*), however. In a study in a large marsh area in Pennsylvania in 1965–1967, ERNST (1967) found *G. muhlenbergii* to be the rarest of all chelonian species present at a proportion of 0.8%. The other species were recorded at frequencies of *Chrysemys p. picta* 76.3%, *Sternotherus odoratus* 4.5%, *Chelydra serpentina* 3.5%, *Terrapene carolina* 2.3%, and *Glyptemys insculpta* 2.3%. Syntopic herpetofauna in these marshes included the Black Rat Snake (*Pantherophis obsoletus*, previously *Elaphe o.*

obsoleta), Common Watersnake (*Nerodia s. sipedon*), Eastern Ribbon Snake (*Thamnophis s. sauritus*), and amphibians like the Green Frog (*Lithobates clamitans*, previously assigned to the genus *Rana*), American Bullfrog (*L. catesbeianus*), Pickerel Frog (*L. palustris*), Spring Peeper (*Pseudacris crucifer*, a treefrog that used to be included in the genus *Hyla* in earlier years), Northern Cricket Frog (*Acris crepitans*), Fowler's Toad (*Anaxyrus fowleri*), Four-toed Salamander (*Hemidactylium scutatum*), Red-backed Salamander (*Plethodon c. cinereus*), and Yellow-spotted Salamander (*Ambystoma maculatum*).

Predators occur in the shape of large snapping turtles, but also comprise racoon, fox, skunk and possum, and possibly even the American Bullfrog. Snakes may pose a threat to juveniles and eggs, as is the case with, e.g., *Coluber constrictor* (Eastern Racer) and *Lampropeltis triangulum* (Milk Snake). The shells, and in particular those of juvenile Bog Turtles, offer little resistance to these predators, even though we found an adult specimen whose carapace had evidently been gnawed at, but which had subsequently healed completely, and this specimen had obviously survived an attack. When a *G. muhlenbergii* is caught off-guard by a predator it will try and help itself with one or more of the following defensive responses: 1) it may remain entirely immobile, 2) it may just retreat into its shell, 3) it may dive into the bottom mud, 4) it may enter a tunnel under a cluster of vegetation, 5) it may rush to reach the water and dive to the bottom, or 6) it may try to escape by swimming away.

In my care:

Only my half-grown captive-bred specimens are occasionally kept in the company of about same-sized *Sternotherus odoratus* or *Clemmys guttata* of the same sex. Native predators, such as marten, dogs, cats and birds, are kept away by means of grille covers over the pens.

Ecology

Diet

In nature:

Glyptemys muhlenbergii is an omnivore that will feed both on land and in the water. Live prey includes insects and their larvae, locusts, snails and slugs, beetles, spiders, worms, shrimps, small frogs, as well as frog and toad spawn. Prey is located primarily by detecting even small movements. As far as plant matter is concerned, it will feed on various berries, the shoots of marsh plants and seeds, in particular those of *Peltandra virginica*, *Carex* and *Potamogeton*.

In my care:

If a *G. muhlenbergii* detects, for example, a slug moving about, it will first raise its head to obtain a better overview. It will then rush at the prey animal if it continues to move. If it ceases to move, however, it will only be carefully sniffed at and maybe given a tentative bite. If this causes it to move once more, the turtle will attack it wildly with a wide-open mouth and without much aim, which often makes it take in plants or soil at the same time that it will then have to separate laboriously from the actual prey. Such an impetuous aggressive attack on a moving prey animal with the goal of minimizing its chances of escape is otherwise known from several more terrestrial marsh turtles, like *Clemmys*, *Cuora*, *Geoemyda*, *Rhinoclemmys* or *Terrapene* spp.

This strategy of predation has to be taken into consideration at feeding times when several specimens are kept together. Even if every turtle is given a live worm at nearly the same time, a worm wriggling in the mouth of another turtle will be such a forceful trigger that the turtle will drop its own prey animal and rather try to take hold of that worm. Feeding these turtles is therefore best done after separating them or at least when they are widely spaced. But even when I distribute small fish throughout the setup, every turtle that has secured a fish for itself will run away

at great speed with the fish dangling from its jaws, even if it is not pursued by another turtle. It is only once it has reached a spot that it considers fairly safe that it will take the time to tear up and ingest its prey. If during this flight phase the movements of another turtle or myself catch its attention it will immediately be distracted, drop its fish, and approach the fresh source of stimulus with the head held high in anticipation.

The animals in my care are fed mainly with chopped-up fish, predominantly Lesser Sand Eel (*Ammodytes marinus*), North Sea Shrimps (*Crangon crangon*), a variety of other shrimps (Palaemonidae), live earthworms, and slugs. Occasionally, this diet is varied by offering pink mice, mealworms, crickets, beetle larvae or maggots. My subadult and adult *G. muhlenbergii* have access to live plants in their pens, but they rarely make use of them.

I presume that the factor Diet constitutes the greatest difference between Bog Turtles living in the wild and those in my care. I surmise that free-ranging *G. muhlenbergii* are unable to catch as much live prey in nature and therefore have to make do with consuming plant matter more often. This assumption of course implies that the diet for the turtles in my care has an over-proportional animal protein content.

Social behaviour

In nature:

Bog Turtles are loners even though they live in colonies. Their colonies do not equate to being socially structured societies, but rather constitute populations devoid of relationships that form within relatively confined spaces due to their posing specific demands on a natural habitat.

ZAPPALORTI (1976) reported on an encounter between two males. Both first tried to identify the sex of the opponent, then each one would turn his head to the side in order to impress the other with his large coloured spot. Fighting then began with threatening gestures with the

mouth agape, followed by bites aimed at the adversary. This will often be enough for one contender to give up by retracting his soft body parts into the shell or by fleeing the scene. Mutual biting of every body part within range may but also continue for up to ten minutes. As soon as the inferior male tries to run away, the victor will often pursue him and effect more bites to the fleeing individual's hind legs, tail and rear margin of the carapace. It is common that the defender of a territory will assert his authority vis-à-vis the intruder as long as the latter is not physically superior.

If a male identifies in an encounter that the other animal is a receptive female based on her scent, be it on land or in the water, he will typically take to courting her right away. The female may then tolerate his advances and let him mount her, or a wild pursuit may ensue; the richly structured marsh habitat makes it relatively easy for a female to escape.

ZAPPALORTI & FARELL (1980) found up to five Bog Turtles sharing a hibernation quarter. In a very large colony of 132 specimens in Sussex County, New Jersey, they worked out the following age class and sex ratios: 12.1% hatchlings in their first year of life (very difficult to find), 4.5% juveniles (1–4 years of age), 7.5% subadult males (4–6 years of age), 6.2% subadult females, 29.5% adult males (older than 6 years), and 40.2% adult females.

In my care:

I kept my founder specimens, 1 male, 3 female *G. muhlenbergii* (Specs. 1–4), together in my 5.7 m² communal pen for many years and never noted any problems. While I sometimes witnessed pursuits and mating activities, I often saw both sexes basking peacefully next to each other. This changed for no apparent reason after some years. It was during one spring when I noticed that only the male would occupy the thus-far most popular basking spot at the edge of the artificial swamp whereas the females had taken to clustering in another spot some 1.5 m distant. My suspicion as to what

may have caused this change in habits was confirmed when I experimentally removed the male from this group: it only took two days before the females had all returned to the prime basking spot. Counterchecking by returning the male resulted in the basking spots being widely spaced once more. My male (Spec. 1) had obviously become sexually mature and developed a dominant streak as he grew older.

I responded by keeping the male in a terrarium of his own from this point onwards. Over and above the problems during feeding already described before I noted over the following years that Spec. 3 of the three females remaining in the communal enclosure was becoming dominant, which eventually also showed in the production of eggs, and in particular in the fertilization rates. The hatchlings I obtained over the subsequent years were for some 80% those from this dominant female. For the last ten years, I have therefore been keeping the three females one by one as well during the mating and oviposition seasons; my initially designed 5.7 m² communal pen had become a much oversized singular enclosure! This measure, however, resulted in a significant increase in the numbers of fertile eggs from the less dominant females (Specs. 2 and 4). In general it is advisable to not keep both sexes together for longer periods of time in autumn in particular. The females try to evade the attentions of the male by burying or hiding themselves. They bask less extensively, and they feed more poorly, and either is counterproductive considering that it is right now that they require a lot of energy for the imminent hibernation period and the formation of eggs in the following spring.

These realizations are a gross mismatch compared to the “minimum requirements for the keeping of reptiles” that serve as a basis for the issuing of keeping permits and spotchecks by the local authorities. Incomprehensibly, these make no difference between the sexes and are solely based upon the number of specimens to be housed! The values obtained thus are entirely useless for keeping *Glyptemys muhlenbergii*.

Diel and annual behaviour

In nature:

Of all diurnal chelonian species, *Glyptemys muhlenbergii* has the shortest activity periods both during the day and during the year. This means that they spend a very long time hibernating, in fact, up to six months, buried in the ground from a few centimetres to a depth of 55 cm (ERNST & LOVICH 2009). Substrate temperatures during this period range from 0.8 to 16.3°C, and cloacal temperatures of the turtles from 2.6 to 16°C. FEAGA (2010) reported that a Bog Turtle survived 20 days at a constant ambient temperature of between -1 and 0°C. The substrate in which the animals bury themselves typically consists of moss, mud and plant fragments at all stages of composting. Some specimens were found and found again in the same communal hibernation quarters for years. They will sometimes select an underground spring for this purpose where the constant temperature of the seepage keeps them from freezing to death. They were also found hibernating in the burrows of muskrats, 1.0–1.8 m from the entrance, and buried underwater in the mud 3.0–7.5 cm deep.

In New Jersey, Bog Turtles emerge from their hibernation quarters around the end of March and in April when air temperatures increase to some 18°C. They now depend heavily on direct insolation and basking for thermoregulation. This will take them to elevated spots or climb dry clumps of grass already in the morning hours. Once their body temperature has reached a good 20°C they will start foraging for food. When air temperatures exceed 30°C, they will take to shaded locales or bury underground.

May or early June, at temperatures from around 25°C, sees them becoming increasingly interested in reproductive activities. The males will now actively search for females, undertaking long journeys both in the water and on land, and returning to their territories only after the mating season to recover from the strains

by basking and feeding. By about June, the marsh grasses will have grown around a metre tall and cast a lot of shade in places during the summer while water levels decrease and the marsh will shrink. The turtles now spend the hottest days in their underground cavities or concealed under plant debris or dead wood; even concrete drainage pipes may be used for this purpose (NEMURAS 1967). A second activity period in September and October serves the turtles to build up reserves for the impending hibernation period.

Approximately 80% of all field records are made in spring, which is the main activity period of this secretive species. In a multi-year study, ZAPPALORTI *et al.* (1979) found 0.8% of the animals in March, 10% in April, 39.2% in May, 22.5% in June, 5.8% in July, 0% in August and September, 13.3% in October, 6.7% in November, and 1.7% in December.

ZAPPALORTI *et al.* (1979) recorded their finds of *G. muhlenbergii* in great detail, a few examples of which are recited here (comp. Table 1):

Sunny days in spring make the turtles emerge from their shelters between 8:00 and 9:00 h, when the air temperature has reached 18°C. They will then bask perched on tufts of grass lining the margins of the marsh. Rarely will they go onto land for this purpose; they prefer to take to very shallow spots in the water and expose the back of the shell to the warming sunrays. ZAPPALORTI measured cloacal temperatures between 15 and 23°C in basking specimens, whereas those moving about and foraging afterwards produced values of 23–27°C. Active turtles had cloacal temperatures of 13.5–34.2°C.

Food is searched for with the head extended forward in the water, and with the head raised high on land. The turtles orientate themselves primarily with their sense of smell and secondarily visually in the water, and in reversed priority on land. Summer sees them retreating into their shelters over noon from about 36°C air temperature, and the second diel activity

Date	Time of day	Cloacal temperature	Substrate temperature	Air temperature	Activity when spotted
08. Apr.	14:15 h	10.6°C	11.5°C	6.3°C	10.5 cm deep in water
28. Apr.	14:50 h	19.4°C	18.2°C	19.3°C	basking in the mud
07. May	11:35 h	26.5°C	17.0°C	17.0°C	basking at a tuft of grass
07. May	13:45 h	18.0°C	10.5°C	17.0°C	basking in front of cave
13. May	11:00 h	11.9°C	10.9°C	14.0°C	basking in stream
13. May	13:35 h	10.0°C	9.0°C	14.2°C	resting deep inside cave
13. June	14:00 h	23.1°C	18.8°C	18.8°C	eating a dead butterfly
23. June	11:15 h	26.2°C	24.0°C	25.8°C	moving about in stream
29. Oct.	14:00 h	9.4°C	9.4°C	8.0°C	hibernating inside cave
18. Nov.	15:00 h	11.4°C	13.2°C	11.9°C	resting in front of cave
29. Dec.	15:00 h	1.9°C	2.0°C	-5.0°C	hibernating inside cave

Table 1: Activities of *G. muhlenbergii* in New Jersey (ZAPPALORTI *et al.* 1979)

period is shifted to the later afternoon hours. In spring and autumn, they will end their days already around 17:00 h.

ZAPPALORTI (1983) encountered *G. muhlenbergii* being active as follows: 8.1% were moving about on dry land, 26% were basking on tufts of grass or on mud, 5.7% were basking in front of their caves, 30.1% were moving about in a stream, 26% were buried in the bottom mud, and 4.1% were sheltered in their caves (Fig. 7). Most animals were discovered between 11:00 and 16:00 h, rarely were they spotted active after sunset unless they were busy with egg deposition. CHASE *et al.* (1989) found 7–213 Bog Turtles per hectare in nine different habitats in Maryland; colonies had an average content of 44.2 individuals. They discovered 38.6% of the specimens outside of the water and 61.4% in the water. Of these, only 6.1% were located in animated water, 2.3% in rivers, and 88.9% of the turtles detected in the water were situated in shallow sections of up to 8 cm deep, with the greatest depth at

which specimens were found measuring 20 cm. 95.1% of the turtles encountered were located less than 10 cm from plant cushions, and 58.7% of those found on land were situated less than 20 cm from the waterline, with the maximum distance being about 7 m.

ERNST (1976) recorded migrations over distances of 225 m per week on average, but studies conducted by LOVICH *et al.* (1992) revealed that males would relocate by 2.1 m and females by 1.1 m per day on average. *G. muhlenbergii* has a great site and territory fidelity, which is emphasized by experiments to this effect undertaken by HOLUB & BLOOMER (1977): they released specimens at distances of 300–800 m from their spots of capture and found that these would return to their home turfs within the space of a day.

In my care:

While LAMBERTZ & LAMBERTZ (2003) overwintered their Bog Turtles in a refrigerator at temperatures of 4–6°C from November

through January, those in my care spend the entire year under largely naturalistic conditions. They will hibernate buried in the mud from November through February. When they were spending their first winter in their 5.7 m² enclosure I expected them to resurface in March, eagerly initially and increasingly worried soon thereafter. After I had not seen them for months, and while my *Clemmys guttata* and *Glyptemys insculpta* had long become active once more, I eventually took to searching for my Bog Turtles with my arm in the mud up to the elbow, following their compost-lined tunnels in the muddy bottom substrate – without success! Ten days later, however, I was greatly relieved to find them basking.

The air temperatures in this glass house rise to slightly higher values on sunny days at this time of the year than they would in New Jersey, which explains why my animals awake from hibernation a little earlier than in nature. Days

with little sunshine then see them returning to their shelters. It will therefore be not before the end of March that I can once more watch them almost every day and before they resume feeding. Their behaviour otherwise largely matches that reported from the wild. I let the vegetation in their pen grow tall in July and August, and the turtles will bury themselves and feed less when temperatures rise above 35°C. The vegetation is cut back in autumn as to improve insolation once more, and I condition them for their impending hibernation by intensified feeding.

Due to my inattention, air temperatures decreased to, and remained at, -7°C in one glass house for several consecutive days. Here, I had accommodated seven *G. muhlenbergii* one by one in seven enclosures of about 0.7 m² with a water level of 7 cm each that were lined up on a bench. Because the cold could impact on these enclosures in this situation from six sides, including in an unnatural



Fig. 7: R. ZAPPALORTI feeling with his arm elbow-deep in the mud for a certain turtle in its "home".

manner from below, I eventually found these turtles encased by sheets of ice about 5 mm thick, like in a suitcase made of ice. They were completely inert, and I wondered how I could possibly liberate them without killing them in the process. I did not dare to crack open the top layer of ice, but instead poured hot water on it and drilled in some holes. This eventually allowed me to lift the ice packs out of the tin tubs and free the captives with great care; luckily, they all survived!

Reproduction

In nature:

Both sexes of *G. muhlenbergii* become sexually mature between the 5th and 7th year of life, when they will have grown to 80–85 mm in carapace length. The sex ratio varies from 1:1 to 1:2, males to females.

In my care:

It is notable that most of the captive-bred females in my care produced their first clutches

unexpectedly late. Although Spec. 6 laid her first eggs at an age of five years, this happened only in the 9th year in Spec. 5, in the 13th in Spec. 7, and even only in the 16th year in Spec. 8 (Table 2)! In contrast, male captive-breds in my care will become sexually very active already at an age of 3–4 years which is when they have to be housed on their own.

Mating

In nature:

Mating events take place on land or in the water, at any time of the day, and mainly in the months of April and May. The latest mating event ZAPPALORTI (1976) witnessed in the wild was recorded on 18 June. He distinguished between three phases: 1) sexual identification, 2) aggressive biting, and 3) mounting and copulation. In the first phase, the male will try to identify the sexual identity of another turtle by visual and olfactory inspection. To this end, he will sniff the rear end, tail and the region of the cloaca. This is



Fig. 8: Bog Turtles mating on land in nature on 4 May 1980.



Fig. 9a: Mating in the embankment zone of my large enclosure on 17 April 2021; male Spec. 1, female Spec. 4.



Fig. 9b: The female has buried herself deep into the mud under water, but the male is not deterred by this.



Fig. 9c: About 20 minutes later: the mating business is finished, and the male slowly lets go of the female.

followed up with bites to the head and neck. A female will respond by either retracting the head and limbs into her shell or by running off. The latter will then often cause a wild pursuit to ensue during which the male tries to stop the female with more bites to the head and legs. If a fleeing female runs into an obstacle and is temporarily halted, the male will try to make the most of the opportunity. The male will mount her in a hectic manner while taking hold of her with all four feet on the edges of her carapace. He will also extend his neck and try to subdue the female with bites from above. I was able to witness this procedure once on land for ten minutes in the wild (Fig. 8), but for what must amount to several hundreds of times in my terrariums. ZAPPALORTI *et al.* (1979) once happened upon three specimens in mating position in a muddy depression 2 cm below the water surface, where two males had mounted one female. BARTON & PRICE (1955) reported about a mating event under water in which the male was knocking his plastron against the female's carapace while releasing air bubbles from his nostrils.

In my care:

Mating events in the turtles in my care have never led to problems such as injuries or even entailed the risk of the female drowning as had been described by SACHSSE (1974) and which sometimes happens in *Glyptemys insculpta*. The entire mating procedure takes about 35 minutes. I often observed several copulation events between one male and the same or different females in a single day. The females involved either resigned themselves to the situation in a defensive posture, or tried, usually with the head retracted, to escape, but never managed to lose the male (Figs. 9a, b, c). The male will even attempt to hastily mount and bite a fleeing female. Mating attempts will be particularly wild in character during feeding sessions, no matter whether live or dead prey is offered.

Oviposition

In nature:

Eggs are deposited in nature during the months of May, June and early July, usually during the later hours of afternoon and in the evening, about 21–31 days after copulation. For this purpose, the female will take to an elevated spot, like a clump of grass, a *Sphagnum* cushion on the edge of the marsh, or seek out soft bottom substrate on an embankment. HOLUB & BLOOMER (1977) described the process as follows: at 21:00 h they observed a female moving against the current in a stream; at 21:15 h she had reached a patch of open grassland that was sunlit during the day, until 21:44 h she took her time to examine the ground with her nose before she started excavating a nest with her hind legs; by 22:00 h she had completed the nest pit, and at 22:16 h she produced her first egg and adjusted its position in the pit with her hind legs. Three more eggs followed at intervals of 40–50 seconds, and she began refilling the nest pit six minutes after the last egg. Inserting five resting breaks of three minutes each, she completed her task by 23:15 h with compacting the surface with her plastron.

Bog Turtle nests are 3.8–5.1 cm in depth and have a diameter of some 5 cm. A female may lay 1–6, usually 2–4 eggs once a year. Young females produce only 1–3 eggs per clutch in their early years. The eggs are elongated and soft-shelled. Their dimensions vary from 21.8–36.5 x 13.0–17.0 mm, with a mean of 29.5 x 15.1 mm (length x width). Particularly suitable nesting spots may host clutches from several females side by side. ZAPPALORTI (1976), for example, once found the remains of two clutches that had been deposited next to each other and subsequently been raided by a racoon. On further examination he discovered a third and intact one of four eggs a little deeper.

In my care:

HERMAN (1986) reported from the Atlanta Zoo of repeated oviposition events entailing

six eggs each, and once of a female that produced two clutches in one year with two and five eggs, respectively, 31 days apart. For his part, WRIGHT (1918) recorded an instance of a captive-kept female laying three eggs in total as one egg each at intervals of 30–40 days. Similar observations were reported on by BARTON & PRICE (1955) and REED & WRIGHT (1909) who noted clutches being produced at intervals of 1–2 weeks.

I made the same observation in the first year of having a female in my care. My explanation for this discontinuous mode of oviposition, i.e., in instalments, is that the respective female is under stress from being placed in a new and unfamiliar environment, because this female continued to produce only one clutch per annum during all the subsequent years just like all others. Making this connection took particularly long in the case of Big-headed Turtles (*Platysternon* spp.) (PRASCHAG 2013, 2014).

The three females of my founder stock, of which I received two as adults and one as a subadult, and which all had presumably hatched in nature, have produced a total of 77 clutches with altogether 267 eggs by today, including 2020. Never mind a few years without clutches, each female had an average output of 0.80 clutches with 3.47 eggs each per annum. This corresponds largely with the figures we know from the wild.

My captive-bred females likewise had 0.82 clutches per year, but the contents of these averaged 4.89 eggs per clutch. This figure is significantly higher than what has been recorded from nature, in particular when it comes to young females. Unnaturally great clutch frequencies and numbers of eggs like this I have been noting in several turtle species in my care (PRASCHAG 1983).

The following is an overview of the numbers of eggs per clutch that I could harvest from my three founder females/compared to those females hatched in my care: clutch of 1 egg: 1/0, of 2 eggs: 12/1, of 3 eggs: 21/4, of 4 eggs:

35/11, of 5 eggs: 5/9, of 6 eggs: 1/8, and a clutch of 7 eggs: 0/5, (Table 2). This suggests that the number of eggs per clutch does not solely depend on the size of the mother animal (RYAN 1981), but also results from how a female was raised. This connection becomes even clearer when considering that clutches with 1–4 eggs were predominantly produced by my wild-caught founder specimens, while clutches with 5 eggs, even more so in those 9 with 6 eggs (eight out of nine), and all 5 with 7 eggs constituted outputs by my captive-bred females.

The dimensions of the eggs produced by my founder females ranged from 29.0–34.5 x 14.0–18.0 mm, with a mean of 31.91 x 15.31 mm. Eggs laid by my captive-bred females were smaller, especially during their first years of reproductive activity.

My large breeding setup offers spring temperatures like those in North Carolina. It is here where my female *G. muhlenbergii* will deposit their clutches in the period between 15 May and 8 June. In those of my enclosures where temperatures more resemble the conditions in northern New Jersey, oviposition events are recorded from 5 through 17 June. The eggs are mostly elongate in shape, with a straight long axis, but sometimes they also have a slight kink and then be more bean-shaped. When egg-laying is imminent, I make available fresh *Sphagnum* cushions near the water's edge in well-insolated spots. The females in my care will promptly respond to this measure by visiting these locales over the next days and apparently subjecting them to tests for suitability as nesting sites with the head held low and lightly digging in them with the front legs. Owing to the fact that the *G. muhlenbergii* will return to their shelters already around 17:00 h in May, a female that has remained outside and keeps on examining a spot beyond 18:00 h will provide me with an indication that she intends to deposit her eggs still this evening. She will then typically start excavating a pit with the onset of

dusk or slightly before, and be finished with closing it up by 23:00 h or a little later. On several occasions these females tolerated my watching them closing and compacting their nest pits after dark in the peripheral shine of a torchlight. The movements of their hind legs to this effect are reminiscent of human hands knitting.

Egg development

In nature:

Based upon several studies, ERNST *et al.* (1994) specified incubation periods of 42–80 days in both nature and in captivity. ZAPPALORTI *et al.* (1997) compared in the 1990' the hatching successes of *G. muhlenbergii* clutches in various marshes in Pennsylvania with those of clutches removed from the wild for incubation in the laboratory. One example from their results: ten clutches of *G. muhlenbergii* with altogether 33 eggs from a marsh in eastern Pennsylvania were found in 1993. Of these, 21 eggs were left in situ, and 12 were taken to the lab and artificially incubated there. Of the 21 eggs left behind, 10 (48%) fell victim to nest raiders, 2 were found cracked, 3 failed to develop, and only 6 (29%) eventually hatched! The 12 eggs in the lab hatched for a 100%. Summarizing their studies from 1993 through 1997, they stated that the hatching success of a total of 131 *G. muhlenbergii* eggs left in three wild locales amounted to 14–59%, compared to 40–100% amongst eggs incubated in the laboratory. Losses due to nest raiders summed up to 12–57%! These percentages improved when clutches were protected against nest raiders with wire mesh cages. Other destructive factors in nature claiming eggs include storms, heavy rains, flooding, overheating and early frost. Hatchlings hibernating in their nests are known from populations from Pennsylvania to New Jersey.

In my care:

Fertile eggs laid by my turtles are notable for their having produced a chalk-white spot

of up to 1 cm in size on the upper side by the next day, i.e., within 12 hours. This spot will then continually expand until the white colour has spread to cover the entire egg after a few days. Uncovering a nest for a routine check revealed that the eggs were peppered with water droplets. This must have been condensation, suggesting that the eggs had a temperature that was lower than the condensation point of the relative humidity at the time of the check. It is in this manner that the eggs take in water and gain in both girth and weight. ZOVICKIAN (1971) noted that while the eggs remained unchanged in length, their diameters would increase to 20–25 mm.

ZAPPALORTI incubated the eggs at 29.5°C during the day and 25°C at night, resulting in their hatching after 45 days. Applying a constant incubation temperature of 26°C had them hatching after 48–58 days in his care. Incubation periods of 40–50 days were recorded in Fort Worth Zoo, but the subsequent raising of the hatchlings was found to be problematic. ELLEN NICOL (pers. comm.) presumed this to be a consequence of an underdevelopment of important inner organs in their 40–50-day hatchlings (see also NICOL 1984). I believe that incubation temperatures had been too high in these instances and did not correspond to the natural conditions.

I encountered problems with hatchlings that burst their eggs already after 45–50 days as well: either they emerged with very large yolk sacs or they suffered from problems with their sense of balance. I therefore took to, and have for years been, incubating the eggs at temperatures that will oscillate in a day/night rhythm between 22 and 29°C. These conditions produced predominantly 80% females. ERNST (2001) stated that it was still unknown whether the formation of the sexes in this species were genetically induced or determined by the incubation temperature.

For incubation, I place the recovered eggs on peat moss (*Sphagnum*) and cover them with a 3–5 cm layer of the same substrate,

Specimen/ Sex	Founder specimens				Captive-bred specimens			
	Spec. 1/ male	Spec. 2/ fem.	Spec. 3/ fem.	Spec. 4/ fem.	Spec. 5/ fem.	Spec. 6/ fem.	Spec. 7/ fem.	Spec. 8/ fem.
received CL age mother	27 Aug. 81 25.5 mm ca. 6 weeks?	16 May 87 91.0 mm ca. 8 years ?	18 May 87 92.0 mm ca. 9 years ?	18 May 87 82.0 mm ca. 5 years ?	09 Aug. 89 26.0 mm 0 Spec. 3	03 July 92 25.5 mm 0 Spec. 3	09 Aug. 95 24.5 mm 0 Spec. 2	14 July 97 27.0 mm 0 Spec. 3
1987			4 on 19 July 31.4x15.4					
1988		3 on 17 July						
1989			4 am 11 June		hatched			
1990 CL Eggs	96 mm	92 mm 2 on 06 July.	93 mm 3 on 30 May	86 mm	43 mm			
1991		2 on 05 July.	4 on 09 June.	2 on 07 July				
1992		3 on 07 June	4 on 15 May.			hatched		
1993		2 on 30 May.	4 on 30 May	3 on 12 June				
1994		3 on 06 June. 33.0x15.5	?					
1995		4 on 05 June 32.6x15.25	4 on 26 May				hatched	
1996		4 on 12 June.	4 on 25 May	6 on 31 May				
1997		1 on 21 June. 34.0x15.0	4 on 15 May.	4 on 24 May 30.1x16.1		4 on 23 May 28.25x15.1		hatched
1998		2 on ? 28.5x15.25	2 on 28 May 32.5x16.75	4 on 08 June. 29.9x16.25	2 on 14 Apr. 27.8x13.25			
1999		4 on 24 May. 32.9x16.75	5 on 05 June. 29.6x16.2		5 on 01 June.			
2000 CL	98 mm	93.5 mm 5 on 10 April 33.3x14.6	94 mm 4 on 18 May 31.6x17.0	89.5 mm	95 mm 5 on 02 June. 29.2x15.5	94 mm 4 on 07 June. 31.0x15.6	81 mm	78.5 mm
2001			3 on 16 May	4 on 01 June 31.1x16.0	3 on ? 31.8x14.0			
2002		3 on 13 June 35.0x15.2	4 on 19 May 32.75x16.5	4 on 06 June 30.1x15.6	5 on 03 June 30.7x16.1	4 on 07 June		

Specimen/ Sex	Founder specimens				Captive-bred specimens			
	Spec. 1/ male	Spec. 2/ fem.	Spec. 3/ fem.	Spec. 4/ fem.	Spec. 5/ fem.	Spec. 6/ fem.	Spec. 7/ fem.	Spec. 8/ fem.
received CL age mother	27 Aug. 81 25.5 mm ca. 6 weeks?	16 May 87 91.0 mm ca. 8 years ?	18 May 87 92.0 mm ca. 9 years ?	18 May 87 82.0 mm ca. 5 years ?	09 Aug. 89 26.0 mm 0 Spec. 3	03 July 92 25.5 mm 0 Spec. 3	09 Aug. 95 24.5 mm 0 Spec. 2	14 July 97 27.0 mm 0 Spec. 3
2003		3 on 02 June 34.8x15.5	4 on 27 May 32.0x16.25	4 on 28 May		4 on 27 May 28.5x15.5		
2004		4 on 01 June 31.75x14.88	4 on 30 May 31.6x16.4	3 on 05 June	6 on 02 June 27.6x15.4			
2005		3 on 28 May 33.0x15.3	4 on 24 May 32.6x16.6		4 on 26 May 29.75x15.9	6 on 31 May 29.5x15.75		
2006		3 on 13 June	4 on 28 May 31.0x16.0		3 on 12 June	6 on 26 May 29.9x16.1		
2007		4 on 03 May	4 on 18 May 30.3x16.2	7 on 13 May	6 on 14 May			
2008		4 on 02 May 31.4x14.7	4 on 10 May 32.45x16.3	4 on 14 May 28.7x15.54	4 on 04 May 28.75x16.25	4 on 19 May 29.75x15.9	5 on 11 May 30.56x15.84	
2009		3 on 21 May 32.7x15.7	5 on 16 May 29.9x16.7	4 on 22 May 29.6x16.0	6 on 13 May 27.2x15.9	3 on 21.05 29.3x15.2	6 on 02 June 29.83x16.0	
2010 CL	97.5 mm	93.0 mm 2 on 14.06 32.0x14.75	93.5 mm 3 on 23 May 33.0x16.7	89.5 mm	95.0 mm	94.0 mm	4 on 23 May 32.0x16.0	
2011		2 on 13 June 33.75x14.75	?	3 on 15 May 31.3x16.0	7 on 27 May 28.93x17.1 +27.05.	4 on 05 May 31.0x16.1 +13.06.	7 on 19 May 28.1x15.5	
2012							3 on 28 May	
2013		2 on 02 June 33.25x15.0	3 on 29 May 32.0x15.5	2 on 06 June 30.0x15.0				5 on 06 June 30.3x15.9
Specimen	1	2	3	4	5	6	7	8
2014		3 on 26 May	4 on 25 May	3 on 26 May			5 on 08 June	4 on 03 June
2015		2 on 03 June 32.5x14.75	3 on 24 May	4 on 03 June 28.87x15.75			5 on 21 June + 21.06.	6 on 28 May
2016		3 on 27 May	4 on 24 May	3 on 28 May				6 on 28 May

Specimen/ Sex	Founder specimens				Captive-bred specimens			
	Spec. 1/ male	Spec. 2/ fem.	Spec. 3/ fem.	Spec. 4/ fem.	Spec. 5/ fem.	Spec. 6/ fem.	Spec. 7/ fem.	Spec. 8/ fem.
received CL age mother	27 Aug. 81 25.5 mm ca. 6 weeks?	16 May 87 91.0 mm ca. 8 years ?	18 May 87 92.0 mm ca. 9 years ?	18 May 87 82.0 mm ca. 5 years ?	09 Aug. 89 26.0 mm 0 Spec. 3	03 July 92 25.5 mm 0 Spec. 3	09 Aug. 95 24.5 mm 0 Spec. 2	14 July 97 27.0 mm 0 Spec. 3
2017		3 on 04 June 31.5x14.5	5 on 21 May 29.8x16.5	5 on 06 June 27.75x15.75				7 on 30 May 29.57x16.65
2018		4 on 28 May	4 on 25 May	4 on 01 June				5 on 30 May
2019				3 on 18 June				4 on 27 June
2020 CL Age	97.5 mm 39 years	92.5 mm 41 years 4 on 07 June 29.75x14.1	93.5 mm 42 years	89.5 mm 38 years 4 on 12 June				100.0 mm 23 years 7 on 04 June 28.8x16.3

Table 2: *Glyptemys muhlenbergii*, development, numbers of eggs, oviposition events, and measurements of eggs of the eight oldest specimens in my care, 1987–2020

The columns give
Carapace length (CL) every ten years
Number of eggs, date of oviposition
Average dimensions of eggs of the clutch (length x width)

keeping them slightly moist with rainwater. Hatchlings emerge in this setup after 59–65 days. Infertile eggs change their colour first to yellow and then to yellowish brown within just 1–2 days and will have grown a pelt of mould after a week. It is then at the very latest that I will remove them. Following rather unsatisfactory hatching rates in the beginning, I experimentally left a clutch in its original nest. These eggs proved to be fertile and developed nicely. Three weeks later, however, only a few shreds of egg shells were left – they had been consumed by mice! On another occasion I left the eggs in a nest that I had secured against mice. The outcome was the same: this time the mother turtle had dug them up and eaten them!

Hatching and raising the young In nature:

No observations exist on the hatching of *G. muhlenbergii* in the wild, unsurprisingly so, as studying juveniles in their natural environment is hardly possible due to their highly secretive habits. They seem to be predominantly aquatic initially, spend most of their time concealed in the mud, and ZAPPALORTI sometimes surprised the one or other baby basking in May and June.

No other turtle species, aside from soft-shelled turtles (Trionychidae), depends as much on a suitable bottom substrate for its survival as does the Bog Turtle. Being able to find safety by burying in the mud is particularly vital for juveniles. Juveniles in their first year of life are therefore hardly ever seen in the wild.

In my care:

In his laboratory, ZAPPALORTI (1976) discovered in the morning of 28 July that three Bog Turtle eggs were busy hatching. One hatchling had already emerged from its egg and buried itself in the *Sphagnum* moss overnight. The other two eggs exhibited slits from which the heads of hatchlings appeared a short while later. One of these remained in this position for the next three hours before it tore up the egg shell in a sudden exertion of force, exited it, inserted another pause, and eventually buried itself in the nest substrate as well.

I came upon the hatching of three eggs on a 12th of July: at 10:00 h I discovered the hatchling resting across the long axis in Egg 1, Egg 2 had been slit open in places and was leaking a drop of albumen. At 11:45 h, the head of the hatchling appeared from Egg 2. At 15:00 h, the embryo in Egg 1 had rotated within its egg by 160°, while the one from Egg 2 had once more retreated into the shell; Egg 3 was merely slit open. At 8:30 h on the next day, the hatchling from Egg 1 exited its shell at an air temperature of 23°C.

The entire hatching process was timed by ARNDT (1977) at 28.0–109.5 hours, with a mean of 51.2 hours. Hatchlings emerge with carapace lengths of 19.6–28.5 mm (mean 24.0 mm), carapace widths of 12.2–24.8 mm (19.9 mm), heights of 9.8–13.3 mm (11.8 mm), and at a weight of 2.2–4.7 g (3.0 g), corresponding to about 84% of the weight of the egg. Hatchlings from my production measured 25–29 mm in carapace length, with a mean of 27 mm. HERMAN (1987) reported on the hatching of twins in the Atlanta Zoo, which measured 16.0 and 14.0 mm in carapace length, respectively. Following the outline of the egg, the elongate dorsal shell will be highly domed initially, but become flatter and wider within the next few days. Hatchlings often appear with a pea-sized yolk sac that will be resorbed within the next days during which time the hatchlings will not start feeding. The egg tooth below the nose may remain visible for up to two weeks.

Aside from the quality and quantity of food, the growth of juveniles is a function of ambient temperatures and humidity levels. In Pennsylvania, the annual growth period amounts to 140 days. Ideal food, in particular during the first year of life, comprises live mosquito larvae, woodlice, small slugs, worms and similar prey. Exposure to UV radiation is even more important for the babies than it is for the adults. However, considering that small enclosures with a low water level are prone to rapid overheating these must not be exposed to full sun over noon. Shortcomings in supply of high-quality food and UV radiation soon lead to the following signs of malformation: the dorsal shell will take on a lower-than-normal shape, the plastron will bend in the region of the anterior scutes, the soft body parts will remain pale in colour, and the spots on the head will lose their orange hue and fade to pale yellow.

For their first year, I raise most of the offspring from my *G. muhlenbergii* one by one in small plastic containers with a floor space of 20 x 20 cm, without any bottom substrate, in water 2–3 cm deep. These containers are each outfitted with a low rock in the middle that extends from the water and can be scaled for basking. This is also the place where prey in the shape of small slugs is made available. I prefer this more sterile type of husbandry to a naturalistic approach, because it will enable me to more reliably monitor the behaviour, physical condition, and the intake of food in the juveniles (Fig. 10). The young can hide amongst some leaves that are added to their tanks.

In Fort Worth Zoo, juvenile Bog Turtles were fed individually outside their communal tank in order to prevent squabbles over food, but also to curb the soiling of the former. Key factors for successfully raising these sensible dwarfs are not limited to feeding them properly, though, and require that their psychological wellbeing be ensured. Particular attention must therefore be paid to stress caused by overheating, and, on cooler days in



Fig. 10: Captive-bred specimens of 3–4 years old (placed together only for this photograph). Photo: V. INFELD

late autumn, to fungal infections. The latter is first noted around the eyes and on the insides of the joints. When discovered early, keeping the affected animals dry, exposing them to UV light, and adding a fungicide to their water may still prevent the worst. If these countermeasures are not initiated within the first few days, on the other hand, the fungal infection will spread to all soft body parts and the juvenile is doomed. In recent years, I have been trying to escape this problem by overwintering the babies in mud already in their first winter.

From an age of 1–2 years, I have in recent years been keeping my juveniles in a communal enclosure with a floor space of about 120 x 70 cm during summer, likewise without a bottom substrate. This larger enclosure enables me to provide better opportunities for sheltering, and one portion is shaded and the rest

is exposed to natural sunlight without much of a risk of the water overheating. Beginning at an age of 3–4 years, offspring of my breeding are then kept one by one and left to enjoy the naturalistic ambience already described above (Figs. 11–12). This means they now have a muddy bottom available all year round and can spend the winter buried in it. The following March then sees me locating the entrances to their underground cavities 2–3 cm below the water surface from which they will appear for breathing more and more often from now on.

The fundamental question of whether young pond turtles, and in this instance the particularly environment-dependent *G. muhlenbergii*, are better kept and overwintered in sterile or in naturalistic conditions was studied by means of far-reaching experiments by TETZLAFF (2020). He asked, “What if reptiles grew up in a naturalistic environment and could make more



Fig. 11:
My enclosures
for the individual
housing of *Clem-
mys guttata* and
G. muhlenbergii;
the mud is 5–7
cm deep.



Fig. 12:
A 4-year old
captive-bred
specimen in one
of the enclosures
of Fig. 11.
Photo: V. INFFELD

experiences right from their birth? And, does it make a difference to their lives after being released into the wild for how long they have previously lived in such a naturalistic ambience?" Two results of his experiments with Box Turtles (*Terrapene c. carolina*) were: juveniles kept "sterile" were better able to detect and consume the maggots offered as food than those kept in naturalistically outfitted pens! On the other hand, specimens from naturalistic raising conditions grew faster post-release than those from "sterile" enclosures.

My method of raising baby *G. muhlenbergii*, developed over decades, has thus been corroborated in most recent years through the scientific realisations by S. TETZLAFF. The average growth of young *Glyptemys muhlenbergii* is summarized in Table 3.

Life expectancy

In nature:

For an assessment of the practical life expectancy of *G. muhlenbergii* in nature, I have been granted access to the data sheets

maintained by R. ZAPPALORTI. He found and examined a total of 289 specimens in the wild, estimated their individual ages, and this now enables me to sort these data into three age classes: some 33% of the specimens examined could be estimated at being 10–15 years of age, 23% were 15–20 years old, 20% 5–10 years, and, 10% were 20–30 years of age. Those younger than 5 years were represented in a single-digit proportion, and 7% were estimated to be older than 30 years. Here, it needs to be taken

into consideration that small specimens are much more difficult to find. It is nevertheless surprising, considering the multitude of natural predators, that this field researcher encountered not less than 22 turtles that were older than 30 years! The secretive habits of this species thus appear to be a proven strategy to evade natural perils.

Not quite 20 years earlier, ZAPPALORTI *et al.* (1979) estimated the life expectancy of Bog Turtles in the wild based upon the growth rings on their carapace scutes to be



Fig. 13:
Spec. 1 (in the rear)
and Spec. 3 (in the
foreground): the
40-year old male has
retained clear indica-
tions of his juvenile
colour pattern on the
carapace. The female
in front of him may
be older by about 10
years, and her cara-
pace has clearly dark-
ened more, is smooth,
and her former colour
pattern is now diffi-
cult to discern.
Photo: F. Grassl



Fig. 14:
Spec. 2, a female
that I acquired with
well-healed damages
to her marginal scutes
nearly 35 years ago.
Her carapace has also
taken on a much dark-
er hue by now and is
smooth. She should
be significantly older
than 50 years.
Photo: F. GRASSL



Fig. 15:
Spec. 4 should now be a little older than 40 years. When I acquired her 35 years ago, she still sported distinct growth rings on her carapace; It has since changed its appearance in a manner similar to Specs. 2 and 3. Photo: F. GRASSL



Fig. 16:
The largest female of my captive-breds, Spec. 8, has retained her juvenile colour pattern still in her 24th year of life, at 100 mm in carapace length. Photo: F. GRASSL



Fig. 17:
A clutch of *Glyptemys muhlenbergii* in nature. Photo: R. ZAPPALORTI

24–30 years. JONES (1989) came to a similar conclusion and estimated the life expectancy of *G. muhlenbergii* to amount to 30 years, and BEHLER suggested 40 years. ZAPPALORTI (pers. comm.) found a female in 1975 that he supposed to be 15 years old. He marked and released her, and eventually recaptured her in the immediate vicinity of the original location 43 years later in 2018. Accordingly, this female was 58 years old in 2018! Together, we happened upon an old male in northern New Jersey whose carapace surface resembled a steel helmet in that it was entirely smooth, uniform brownish black, and lacked all indications of scute sutures and colour pattern. Compared to the 40-year old male in my care with his rather young looks, this wild male must clearly have been much older than 50 years.

With regard to the genetically possible life expectancy of this species, we still depend on

presumptions, but most recently GRESS (2021) encountered two specimens in the framework of a long-term study in Pennsylvania that were at least 62 years of age.

In my care:

Specimen 1, a male, I received in 1981, and its dimensions at the time indicated it to be just a few weeks old. Today, in the year 2021, this turtle is in its 40th year of life (Fig. 13). Specimen 2, a female, was added to my collection as an adult in 1987 with a carapace length (CL) of 91 mm. She must have been about 8–10 years old at the time and thus is at least in her 42nd year of life now (Fig. 14). Specimen 3, also a female, came to me in 1987 at 92 mm CL. At least 10 years of age then, she has by now lived at least to her 44th year (Fig. 13). As for Specimen 4, yet another female, she was acquired in 1987 when she sported 82 mm CL. An estimated 5 years of



Fig. 18: *Glyptemys muhlenbergii* hatchlings, 1–2 days old, from one clutch laid on 12 June 2021. It hatched on 12 and 13 August 2021; its mother is Spec. 4, and its father likely Spec. 1. The cheek spot is yellowish on hatching, but will change in my offspring to orange after 7 to 10 days, and to orange red over the following months; comp. Fig. 10.

Age / Year	Carapace length (in mm)		Weight (in g)	
	M	F	M	F
0 in July	25	25	3	3
0 in October	31	31	8	8
0 in March	32.4	32.4	13	13
1 in July	38	38	17	17
2	51	50	37	37
3	66	64	63	60
4	76	74	87	85
5	84	82	115	118
7	90	88	125	130
10	93	91	135	145
15	97	93	140	150
20	98	94	143	150

Table 3: Average development of the sexes in nature, compiled from the records of R. ZAPPALORTI

age then, she today lives in her 39th year of life (Fig. 15). The oldest turtle hatched in my care, Specimen 8, left its egg in 1997, and is by now 24 years old (Fig. 16) (Table 2).

SNIDER & BOWLER (1992) stated the longest known period of keeping this species in captivity to be 23 years and 1 month. This record has since been clearly and repeatedly been surpassed by both my founder animals and my oldest offspring specimen.

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