In Pursuit of *peltifer*

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One thing about turtles is that they captivate us in so many ways. They check numerous boxes on the list of things that fascinate us. A 250 kg Galapagos Giant Tortoise lumbering along rocky terrain fascinates those enamored by the concept of size. The desert tortoises of the American Southwest leave us mesmerized by their ability to live for decades (maybe even centuries) in a desolate habitat known for its propensity to expedite death. Turtles abound in folklore, both at a local and international scale. The tales of man-eating giant softshell turtles and snapping turtles as large as SUVs have captured the imagination of humanity for centuries. The significant representation of turtles in nearly every religion cannot go without mention. To some, turtles represent the Gods in reincarnated form. To others, a method of divination or a holy food source. To the scientist, turtles serve an expansive multitude of purposes. Studying the molecular biology of turtles has provided valuable insights into the biology behind aging and its relation to the mitochondria, while studying community ecology of turtles has brought about advancements in understanding animal behavior. And one cannot forget the aphorisms of Aesop's Fables "slow and steady wins the race" – a statement that seems to hold true in most circumstances.

As my friend and I sat on the banks of a Georgia river, in the wee hours of the morning, these were the thoughts that filled our heads. Hours of fruitless searching fraught with stormy weather dampening our hopes had ended, rather unexpectedly, with us finding the animal we were looking for. Both of us have spent a good portion of our 17 years on this planet in pursuit of the Alligator Snapping Turtle (*Macrochelys temminckii*), and to be sitting in front of a formidable 90 lb. male specimen lumbering along the bottom of a clear creek was breeding ground for an unthinkable amount of adrenaline, reflection, and happy thoughts. It's nearly 3:00 AM and we're muddy and soaked, but one does not notice such things when one's world is fixated on a single object that carries so much significance.

After cheers are raised, gasps and *ahs* made, and plenty of pics snapped, our Alligator Snapping Turtle friend is sent on his way back to continue to roam his home stretch of creek. Knowing how quick to judge our species can be, it is easy to see why such an animal would gain such a nasty and disrespected reputation. The foreignness of this species' appearance, of a lineage far older than the dinosaurs, combined with its cryptic habits make for a perfect storm of false interpretations about these turtles. Where many would see a pest reptilian best served as soup wandering off to contemplate its next attack, we see a predominantly mollusk-eating and herbivorous sentient with profoundly positive environmental impacts seeking to escape the iron fist of humanities ignorance.

The story of the Alligator Snapping Turtle's widespread reduction is one often referenced in conservation circles. Diligent work by dedicated conservationists in the latter half of the 20th Century brought about widespread policy change that largely ended the unsustainable harvest of snapping turtles that occurred during the 1970-80s across the southeastern United States. While there is still much to be done in the way of restoring depleted populations, the Alligator Snapping Turtle's uniqueness and place in popular culture, while the result of its temporary fall, has also greatly contributed to its continued restoration and hopeful comeback. Nowadays, what keeps me up at night is not so much the tale of the snapper. I worry more about the future of its much lesser-known cousins.

Prior to our encounter with the Alligator Snapping Turtle, four long days were spent in pursuit of its miniature equivalent, the Stripe-Necked Musk Turtle (*Sternotherus peltifer*). Not only are these diminutive turtles nearly Alligator Snapping Turtle replicates in terms of the ecological niche they occupy and physical form they possess, they are quite literally related by blood as well.

When scientists who study taxonomy (how organisms are classified according to various schemes) want to understand how organisms are related to each other they can use different types of data to inform their conclusions. These informed conclusions are often translated into a phylogenetic tree, whereby the

Fig. 1. Searching for Stripe-Necked Musk Turtles in a Ridge and Valley Creek.

relationships of certain organisms and genera can be visualized. Types of data that are used to construct such trees include morphological (how an organism looks in relation to other organisms), protein assays, and genetics. Much like organisms, the types of data used in classification analysis also evolves as time progresses, and biotechnological capacity increases. This has led most contemporary analyses to rely heavily on large quantities of genetic data to hypothesize how organisms are related to each other, due to the greater coverage and robustness of large molecular datasets.

Fig. 2. The Apalachicola Alligator Snapping Turtle found by Greg Brashear.

Choosing what type of data to use represents only a fraction of a taxonomists work, however. Once a method to infer species relationships has been chosen, a definition of what a species really is must be reached. This requires adherence to a species concept, of which there are many. The basic idea here is that what constitutes a species is not an agreed upon topic, and a species can be defined in many ways. One of the most popular ways, known as the phylogenetic species concept, defines a species as an irreducible group of organisms sharing apomorphic characters, unique attributes only found in that group of organisms. In the case of taxonomy based on phylogenetic trees derived using genetic analyses, a species is a monophyletic clade.

Applied to the case of the Stripe-Necked Musk Turtle, these definitions create a clearer visual. While unique, the Stripe-Necked Musk Turtle belongs to a group of organisms that share certain ancestral similarities derived from a common ancestor. This group of organisms, placed in the genus *Sternotherus* (Bell in Gray 1825, a Greek reference to one of this

Fig. 3. A bend in another creek that is home to Stripe-Necked Musk Turtles.

group's shared similarities, their movable front lobe of the bottom shell, -*sternos* meaning "chest, abdomen" and -*thairos* meaning "movable") forms a monophyletic clade on a phylogenetic tree based on genetic data (Iverson et al. 2013; Spinks et al. 2014). But the madness does not end there, the six members of the *Sternotherus* lineage are a sister group to an even larger group of mud turtles, which are placed in the genus *Kinosternon* (these turtles can move both lobes of the bottom shell upwards, something musk turtles cannot do). Zooming out even more, a few more branches of species groups coalesce to form the family Kinosternidae, which unites all 25 species of mud and musk turtles into one large grouping.

As we zoom out, the situation becomes a bit hazier, as inferring deeper lineage splits becomes more difficult. Current research supports the hypothesis that the entire family Kinosternidae is a sister group to the Central American River Turtles in the family Dermatemydidae (Thomson et al. 2021; Guillon et al. 2012; Joyce and Bourque 2016). This grouping of two families forms the superfamily Kinosternoidea, which appears to be a sister clade to the Chelydridae, the family of North American Snapping Turtles (Thomson et al. 2021; Joyce et al. 2021). Zooming out one more step reveals these two families to form a basal sister grouping to modern sea turtles and their descendants. The sea turtles, snapping turtles, mud and musk turtles, and Central American river turtles coalesce to form the Americhelydia clade of turtles, and the lumping and naming keep on going until you hit the first true Testudine, which is not currently agreed upon.

So we are in pursuit of bite-sized snapping turtles in a very Darwinian sense.

Our search for the Strip-Neck consists of rolling into the driveway of a rural town in mountainous Alabama. All aspects of our biology are worn out. Our legs are tired from consistently using them throughout the week. Our arms are heavy from the countless specimens we have been using them to examine. And our eyes and ears are shot and blasted from road-cruising the Francis Marion National Forest, while going 30 mph with Mac Miller, DaBaby, and 6IX9INE (had music choice been up to us, the playlist would have been quite different) blaring at full volume. The paint chipped Harley strapped down in the back

Fig. 4. A beaver dam on a Coosa tributary. All of the surface area created by the twigs make for good musk turtle lodging.

of our pickup is testament to both the distance, and determination, that have gone into this trip thus far.

We are staying with an upcoming professor of herpetology who is just as eager as us to acquire our target Stripe-Neck. Grover Brown completed his undergraduate studies at the University of Georgia, within the Odum School of Ecology. After a series of travels abroad, including trips to Vietnam to help at the Turtle Conservation Center in Cuc Phuong National Forest and visiting Australia, Grover earned a doctoral degree from Southern Mississippi University. Only a year after defending his thesis, we have intercepted him literally 24 hours after purchasing his new home in Alabama where he is scheduled to start his new job this August.

Grover specifically warned us not to expect much, but we are pleasantly surprised to find floors and functioning water and utilities. We're prepared to forego any form of luxury for turtles, including camping out on concrete foundation for a week if need be. A roof is a welcome surprise, but not a requirement. The house is very nice though. Scars of its past owners litter the walls. Apparently, they had a knack for corny wall phrases, including a ridiculous love adage strung over the king-sized bed for the couple, whose divorce is responsible for the house being sold. Safe to say this did not age well.

Where cheesy boards once hung, Kinosternids now swim. Upon entering Grover's abode, one is greeted by a large 75-gallon tank that houses four turtles. Three of which represent our turtle of interest, the Stripe-Neck, and a lone Common Musk Turtle (*Sternotherus odoratus*). What is different about these Stripe-Necks, however, is that they come from a vastly different locale as the specimens we are after. The three turtles hail from the Pascagoula River drainage of eastern Mississippi, very close to where Smith and Glass first recorded the species in 1947. The authors of the original species description listed the type locality as Jefferson Davis County, Mississippi. However, a few decades later, this locality was contested as certain scientists believed the species to not be present in the Pascagoula drainage, with its westernmost extent in the upper Tombigbee drainage. Valid reports of the species did eventually come from trapping efforts conducted by Dick Vogt and colleagues on the

Pascagoula in the 1970s, confirming the presence of the species there (McCoy et al. 1978). Further work in a drainage even further west, the Pearl River drainage, confirmed the species to even be present here, albeit in very low abundance (Brown pers. comm.). Most reports of Stripe-Necks in the Pearl River seem to come from the southern section within and close to Louisiana. Out of ~140 traps set by Grover around this section only six Stripe-Necks were caught.

While their historical and contemporary geography is interesting, these Pascagoula Stripe-Necks are also very different in form from their counterparts in other drainages. The typical Stripe-Neck bauplan is phenotypically variable, but generally consists of a relatively flattened turtle that possesses only a singular, weak, vertebral keel that disappears with ontogeny. The head possesses striping that circumscribes the neck in a more or less unbroken pattern in young to middle aged specimens. In older specimens, the pattern tends to become more broken and vermiculate. The typical coloration is light/brownish scutes with darker flecking and seams on the top shell, and a light/beige bottom shell. A typical measurement used to distinguish between musk turtles involves taking a piece of string and draping it over the top shell. The string is then removed and aligned with a protractor, and the angle it makes is measured. This angle of the shell is then compared to the shell height and reported as the angle/height (A/H) ratio (Tinkle 1955). Most musk turtles have an A/H ratio of less than 5:1, with only one member of the genus, the aptly named Flattened Musk Turtle (*Sternotherus depressus*) with an A/H ratio averaging 8.5:1, due to its specially adapted dorsally flattened shell designed to wedge into rocky crevices (Ernst et al. 1994). The Stripe-Neck mostly falls below this 5:1 A/H ratio, although in certain circumstances, this may not be the case, as in populations from central Alabama where they have seemingly converged upon the flattened shell shape of the Flattened Musk Turtle and are definitely not hybrids between the two species.

Pascagoula specimens are oddly blonde and seem to lack most of the darker flecking that adorns other populations of Stripe-Necks. Pascagoula Stripe-Necks also have much higher domes to the top shell, and the dome seems to taper off at a point towards the fifth vertebral scute on the posterior half of the top shell. The reasons for these differences are still anyone's guess, but the latter difference may be due to some character convergence between the Stripe-Neck and the syntopic Razorback Musk Turtle (*Sternotherus carinatus*). This species represents the antithetical extreme to the Flattened Musk Turtle, and has a very sharply domed top shell, possibly an adaptation to aid in diving or survival in fast moving currents in the main river channel (Pritchard 1979; Brown pers. comm.). It is interesting to note that both the Flattened Musk Turtle and the Razorback Musk Turtle occur within the same state, with only the former restricted to the Black Warrior and some of its tributaries and the latter restricted to the arms of the Pascagoula that extend barely into Alabama near Mobile Bay.

Enough of the thinking for tonight. All members of our party are exhausted. We pull out our sleeping bags and unravel on the couch. We're asleep before one could say *Chelydra* three times fast.

The next day, we begin our Stripe-Neck search bright and early. After a filling breakfast of Redbull and gas station taquitos, we are off to a nearby forest to begin our search for these turtles. We are in the northeast of Alabama, the mountainous portion of the state. It is a beautiful area, with roads marred on either side by mixed pine-oak woodlands.

Our first search for Stripe-Necks is concentrated on the border of the Ridge and Valley physiographic region. Known for its forests and beautiful scenery, this region was formed roughly 350 million years ago as an after effect of the most recent uplift of

Fig. 5. A small female Common Snapping Turtle found in a unique Beaver Pond habitat.

Fig. 6 An Alabama Map Turtle found under a submerged log in the same habitat.

the Appalachians. It is characterized by the series of uniform southwest-northeast trending ridges that traverse it. Fortunately for small turtles, the ridges that make up this region have been carved out over millenia into narrow streams within the Coosa watershed. Coupled with the surrounding forests, efficient natural filters, and the chunks of limestone scattered throughout, these streams are nutrient rich and productive. In fact, the Upper Coosa is home to the highest percentage of endemic species of any North American river, harboring at least 30 species found nowhere else. The Stripe-Necks have taken a particular liking to this productivity and biodiversity, and have colonized many of these tributaries, taking advantage of the abundance of food. Being bottom-dwelling Musk Turtles, they specialize in the consumption of a variety of benthic invertebrates and plants, including mollusks, insects, and algae. Being opportunistic omnivores – a term that means they will eat anything given the chance – they will undoubtedly broaden their palate in their lifetime. The species particular fancy for Mollusks is unarguably satiated within the Coosa, as they have access to no more than 38 species of snail and mussel to feast upon. In the past, however, mollusk diversity within the Coosa was nearly two times what it is now. Due to the heavy impoundment of this river, and widespread modification and sedimentation that have plagued it since the turn of the 20th century, this region of the United States has seen the greatest short term extinction event in modern history. While Stripe-Neck consumption of mollusks has always been a sustainable practice, humans cannot be trusted to treat our resources in such a responsible fashion.

After driving up a winding dirt road, we stop in a small valley with a stream cutting through it. Grover's experience looking for this species has our hopes high, but the cool morning and cloud cover may keep turtles hiding (this statement is based on pure anecdotes, no one has actually studied whether or not cloud cover makes a difference in activity patterns for this species). The other members of the party, Jack and Ron Thompson as well as Wyatt Keil, are just as eager as me to find a turtle. We hastily get our gear on and enter the stream.

Walking through the clear stream, under the cover of oaks that scatter the sunlight, quickly becomes a reflective experience. My mind is taking in the beauty around me, while simultaneously jumping in and out of thoughts. Being in this ecosystem brings solace during the college application process, even though we are finding no turtles.

No turtles are found at our first high elevation stop. Stripe-Necks were present, just rare enough there that two hours of searching was not sufficient in our case to turn one up. On our way back to our lodging, we make a quick stop at a larger Coosa tributary. As if it were taunting us, the weather decides to unleash a downpour when we exit the car. Our stop at this tributary is quickly refocused into a swim and basking session on a log in the middle.

A bit dejected, we grab lunch and head out to a creek in town. After some falls, laughs, and again finding no turtles, we pack in for our first night. Emotions run a bit hot for the rest of the night. We are both frustrated by our inability to find any turtles as well as by the prospects of what looks to be an incoming storm. If it plays out as the news coverage reads, we won't be finding much.

On day three of our trip, still Stripe-Neckless, we decided to change our plans a bit. Our species of focus switches for the morning, and we set off to a unique spring-fed system where Alabama Map Turtles (*Graptemys pulchra*) and Common Snapping Turtles (*Chelydra serpentina*) abound. To access the site, we traverse a highway and off road into the brush for a few minutes. As we struggle our way through vines and branches, we are met with an incredible sight. The beavers in this area are especially proficient workers and have dammed a small creek to the point that it has become a pond. Given that the source of the pond, not far away, is a freshwater spring, the water clarity is astounding. When in the presence of this natural wonder, it becomes clear why early European explorers wrote of fountains of youth. Ten minutes of frigid water snorkeling turns up two Alabama Map Turtles and two young female Common Snapping Turtles. They seem to stay small at this site for some reason.

Our journey then takes us even further from home base to an obscure town littered with the preparations for 4th of July festivities. The woman behind the counter of the large convenience store with only two shelves makes sure we are aware of the upcoming holiday and urges us to stay for the fireworks.

We get to work wading in yet another crystal-clear creek, cut between two sides of rocky earth. Patches of submerged aquatic vegetation create little mats within the narrow channel. Small pebbles lead our eyes to believe they're Musk Turtles. Our point of entrance to this site is literally adjacent to the main road through town, to the left of which children play in the section of the creek-turned-water-park. To the right of the passageway, the creek runs abutted by backyards, yet relatively untouched. It creates an interesting juxtaposition between humanity and our lesser-known congeners, the Stripe-Necks. It is very unlikely anyone on the left of the road knows of the Stripe-Necks existence, yet the Stripe-Necks still survive not far away.

Greg Brashear of Greg's Turtle Haven joins us for this part of the trip. His local knowledge comes from a lifetime of exploring this part of the country and is a major asset to our adventure. As I am talking with Greg, he informs me that male Stripe-Necks frequently occur on the sandy slopes that lead to the deeper pools within these streams. Not far from the main road, as we round a bend in the creek, the right side tapers off into a deeper pool. Having taken Greg's advice to heart, I begin to deviate from the group and meticulously inspect the portion of sand angled into the deep zone. A particular rock catches my eye. I'm not sure what stood out about it, but the habitat it was in matched Greg's description to a T. I don't hesitate to reach down. As my hand penetrates the water, at least in my recollection of the event, there is a split second of dead silence from the party. Piqued by my initiative, they stand idle. As my hand makes contact with the object, I am certain what I have is a stone. It hasn't scratched or moved one bit, as turtles generally do. Not confident about my judgement, my hand breaches the surface. As I unclasp my fingers, all eyes light up. We have our Stripe-Necked Musk Turtle.

Consistent with Greg's prediction, it is a young male, likely out foraging at this time of late morning. He is caked in algae, and becomes comfortable with us quickly, extending his head and neck and letting us get a closer look at his unique morphology. His chin barbels are the first thing that catch my eye. Unlike their close relatives, the Common Musk Turtle, the Stripe-Necked Musk Turtle only has barbels on its chin. Why they have fewer pairs is not known, nor is the exact function of the barbels understood. They may be ampullary or tuberous electroreceptive organs attuned to certain frequencies, or they may pick up changes in water chemistry. Alternatively, the barbels present on this species may serve an entirely different function.

The next thing that stands out is his size. At only a few inches in length, this turtle, surprisingly, has relatively little more growth to undergo. This species reaches its maximum size at only around 120 mm (~4.7") when full grown, with maximum size similar between the sexes. Interestingly, before the Stripe-Necked Musk Turtle was considered a full species, and rather a subspecies of the Loggerhead Musk Turtle (prior to this, a subspecies of the Razor-Backed Musk Turtle) Dr. Carl Ernst noted that the growth curves displayed by this species was quite different from the growth curve of the Loggerhead Musk Turtle, leading him to believe they potentially represent different taxa (Ernst et al. 1988b). Fast forward to 2017, and Scott et al. conclude that in fact the Stripe-Necked Musk Turtle is more closely related to the Flattened Musk Turtle, with which its range abuts, a third major revision for the placement of this species in recent history.

One cannot see one of these turtles and not appreciate their unique, somewhat quirky, overall appearance. Being relatively drab has served them well over the eons, whether we like it or not. Looking like a rock has its upsides.

Fig. 7. A larger female Stripe-Necked Musk Turtle. This was the second musk turtle encountered by us.

As we got our last looks at this magnificent turtle, I couldn't help but feel like what I was looking at was truly a wise ancient sentient. I refrain from calling turtles "living dinosaurs" because they are not dinosaurs, but if this was an acceptable term, I would have thought this just the same. If something as simple as a musk turtle has etched out a sustainable life here on Earth for millions of years, why is it we seemingly are unable to do so?

In any regard, as I let this turtle back into the water, the last thought on my mind was a hopeful wish that he will soon find a mate and contribute to the long-term survival of his kind. It was mid-July when I came upon him, a period of testicular mass gain for this species, but by around the time of writing this, he is assuredly in the mood to find a mate, his mature spermatozoa beginning to migrate to the epididymis. Just as well as he might significantly contribute to prolonging his kind, he is just as likely dead on a rural Alabama road.

Fig. 8. The third Stripe-Necked Musk Turtle we found. Notice the interesting chromosome-like pattern on the carapace, and how unusually flat it is.

Over the next three days of our trip in Alabama, we managed to find two more female Stripe-Necked Musk Turtles. These specimens were much larger, and one was even surprisingly flat, a welcome surprise. It is an incredible experience finding such lively creatures within some of the most forgotten areas of the United States. Where a company might see the small creek running behind their storefront a nuisance, or pay no attention to it at all, these musk turtles find a home; a whole different world. But this world has been forgotten, or never even known, by most of us here. If we as humans are to keep up with our rapid rate of habitat destruction, sedimentation, and river modification, we might as well dig an early grave for these helpless chelonians. We won't simply be losing yet another keystone of global biodiversity, we will be losing an entire world, a universe, in the loss of the musk turtle's wake. It is not simply the crisis facing the snapping turtle's cousins that keeps me up at night, rather, it is the loss of their domain, and what this says about the future of humanity, and how much time we have left before the damage done by us, can only hurt ourselves.

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