

Turning up the heat: how turtle hatchlings respond to environmental temperature

Featured Scientist: Dr. Amanda Wilson Carter



Birthplace: New York City, NY

My Research: I study how animals are affected by changes in their environment.

Research Goals: I want to understand how changes in temperature affect animal **physiology**. I would like to be able to better predict how **climate change** will affect all types of animals.

Career Goals: I am currently working towards increasing the participation of underrepresented groups in science. My goal is to become a biology professor and researcher.

Hobbies: Traveling, playing with my dogs, and renovating my 1940's bungalow.

Favorite Thing About Science: I love having the freedom to explore questions that I think are necessary and important. Throughout my schooling and career, I have also discovered a passion

for mentoring students through independent projects in the lab. There is something very special about watching an undergraduate conduct their first study and transform into a confident and capable young investigator.

Organism of Study: I study many animals, but my PhD research focused on turtles, mainly the red-eared slider (*Trachemys scripta*). In my current position, I conduct research on dung beetles.



*Red-eared slider turtle (*T. scripta*). Image [source](#)*

Field of Study: Eco-physiology | Climate Change | Plasticity | Development | Parental Effects.

What is Eco-physiology? I broadly consider myself an eco- physiologist. I study how the **physiology** and behavior of animals are affected by their environment (mainly temperature).

Check Out My Original Paper: “Short heatwaves during fluctuating incubation regimes produce females under temperature-dependent sex determination with implications for sex ratios in nature”



QR Code to the original publication

Citation: A.W. Carter, B.M. Sadd, T.D. Tuberville, R.T. Paitz, R.M. Bowden, Short heatwaves during fluctuating incubation regimes produce females under temperature-dependent sex determination with implications for sex ratios in nature. *Sci. Rep.* 8.3: 1-13 (2018).

Synopsis written by: Elyse McCormick, M.S. (Anticipated Spring 2022), School of Biological Sciences, Illinois State University.

Research at a Glance: Temperature is very important for many parts of biology. For baby turtles, it is essential. Many turtles become male or female based on **incubation** temperature. This process is called **temperature-dependent sex determination**, or **TSD**. Warmer **incubation** temperatures make females, while cooler **incubation** temperatures make males. Until now, **TSD** has been studied in lab settings where the **incubation** temperature is held constant. However, since temperature doesn't stay constant in nature, this is pretty unrealistic. Amanda wanted to see what happens to **sex ratios** when turtles experience real, changing temperatures. She hypothesized that changes in temperature are very important to determining sex in turtles that have **TSD**. She predicted that turtles are very sensitive to short exposures to temperatures above the "**pivotal temperature**", or the temperature that will produce a population-wide 50:50 **sex ratio**. She also predicted that ovaries will start to grow within a few days of exposure to these warmer temperatures.

Amanda raised eggs using temperatures that went up and down with daily daytime and nighttime temperatures to mimic what a turtle would feel in nature. She then introduced eggs to short exposures of temperatures above the **pivotal temperature** to mimic heat waves. She was able to show that **sex ratios** can be changed by exposure to very short increases in temperature. Amanda used an Illinois population of the red-eared slider turtle, *T. scripta*, for her research. Under the conditions in this study, *T. scripta* only needed approximately 8 days of exposure to warmer temperatures to produce a 50:50 **sex ratio**. At 5 days under the same conditions, 16% of the turtle **embryos** became female. This shows that even short exposures to warm temperatures can make an **embryo** become female. Amanda's research shows that using natural temperatures can lead to a more accurate prediction of turtle **sex ratios** in nature. Her research also sheds light on another mystery. In Illinois, average temperatures are often so low that female turtles would be unlikely to be born. But somehow, females are still found in the population. Her research shows how female turtles end up in the Illinois population: turtle **embryos** only need a few days incubating under warmer temperatures to become female.

Amanda also wanted to see if **embryos** had the same response to temperature changes across the **nesting season**. She looked at differences between early and late season **embryos** to see how long it took under warmer temperatures to make female turtles. Late season **embryos** required less time at warmer temperatures to produce a 50:50 **sex ratio** than early season **embryos**. Mother turtles increase a hormone called **estrogen** in the **yolks** of their eggs across the **nesting season**, which leads to more females later in the season. Thus, late season **clutches** probably have a 'head start' on other **embryos** because they have more female **hormones** in their **yolk**. As a result, eggs don't need as much time in warmer temperatures to make females. Amanda used the results from her experiments to then develop a mathematical model to better predict **sex ratios** using natural temperatures measured from the field. This model helps predict the number of male and female turtles based on real field temperatures.

Highlights: We just learned that females can be made after just a few days at warmer, **female-producing temperatures**. This finding helps us understand how sex is determined under more natural, changing temperatures. This finding is important because we can now more accurately determine **sex ratios** in turtle populations using available temperature datasets, like those available through the **National Oceanic and Atmospheric Association (NOAA)**. We are currently experiencing changing global temperatures, where turtle **embryos** are more likely to experience warm **incubation** conditions. Being able to predict **sex ratios** in turtles is important for their conservation. We might be able to accurately identify turtle species or populations that are most at risk of 100% female populations, which would be unable to make more offspring. We can use that information to direct conservation efforts and resources.

What My Science Looks Like: **Figure 1** from this paper is a great example of how different field temperatures can be. **Figure 1** reports temperature (y-axis) over the course of the summer **nesting season** (x-axis) for Illinois turtles. The solid horizontal line shows the **pivotal temperature (Tpiv)**. It shows that, on average, temperatures have not been warm enough to produce females in this population for 23 years. But when you break it down by year, there are bursts of temperature warm enough to make females (see 1993 and 2012). In nature, temperature is not constant. Instead, it fluctuates. Amanda had to find a way to test what happens to turtle **embryos** in their natural environment. She needed temperature data from her study area to show that natural temperatures fluctuate around the **Tpiv**.

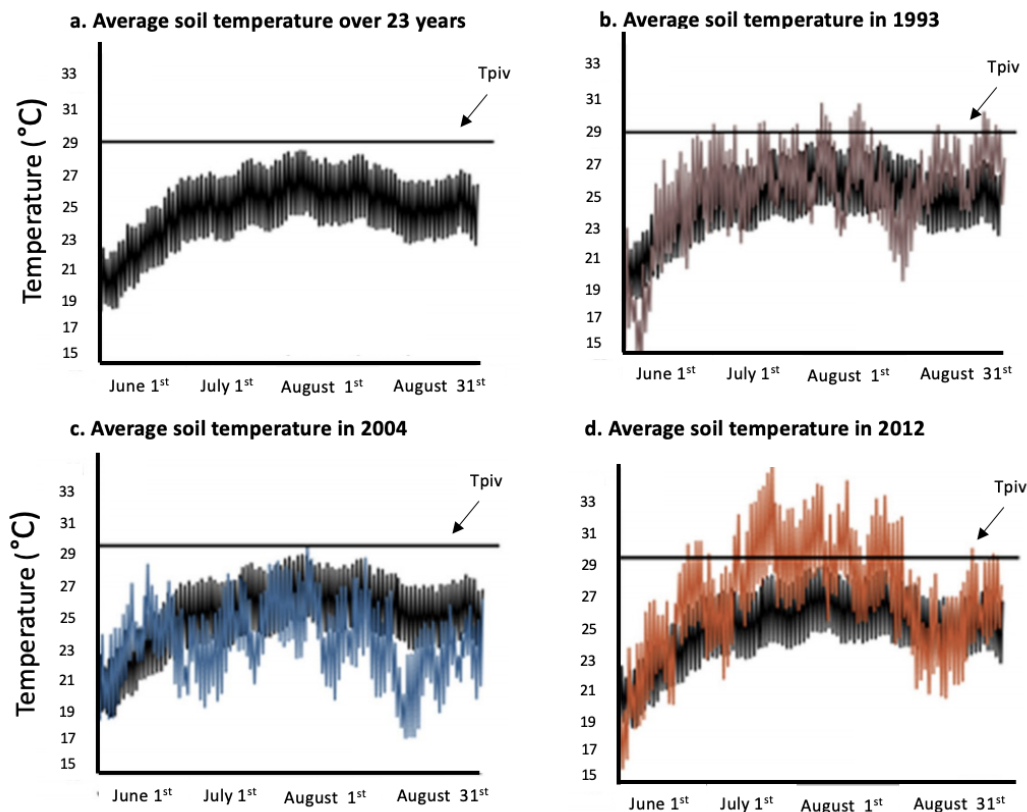


Figure 1. Average soil temperatures from Peoria, IL. *Figure adapted from Carter et al. 2018.*

The Big Picture: Amanda's research took a more realistic look at **TSD**. It allowed her to create a mathematical model to predict realistic **sex ratios** for hatchling turtles. These types of studies allow scientists to better understand what's happening in nature. Knowledge about how turtles live in the wild is important for more than just improving our understanding of turtle biology. They allow us to understand the wide-reaching effects of environmental impacts, such as **climate change**, on animals that are extremely sensitive to changes in temperature. **Climate change** could impact the **sex ratios** of hatchling turtles in ways we don't fully understand yet. But this study allows us to start to understand it. Amanda's model can be used to predict how **climate change** might affect future generations of turtles. It's possible that her model can help us understand how **climate change** will affect turtles, as well as the animals and plants that they interact with. If we can understand how **climate change** might impact a broad array of plants and animals, we may be able to help lessen its effect on our environment.

Decoding the Language:

Climate change: A change in global or regional climate patterns, often seen as major changes in temperature or precipitation.

Clutch: A group of eggs that are laid together at the same time by a single female.

Embryo: An unborn or unhatched offspring that is actively growing. In the context of Amanda's research, the embryo is the developing turtle inside the egg.

Estrogen: A steroid hormone that promotes the development and maintenance of female characteristics in the body.

Female/Male-producing temperatures: Female-producing temperatures are higher/warmer temperatures that cause red-eared slider turtles to become female. Male-producing temperatures are lower/colder and cause these turtles to become male.

Incubation: The process of keeping an egg warm enough to develop until hatching. In the context of Amanda's research, a male-producing incubation temperature is approximately 26°C and a female-producing temperature is approximately 31°C.

National Oceanic and Atmospheric Association (NOAA): A scientific agency within the United States Department of Commerce that focuses on oceans, major waterways, and the atmosphere.

Nesting season: The duration of time that animals are actively laying eggs. In the context of Amanda's research, the nesting season lasts from late May to early July.

Temperature-Dependent Sex Determination (TSD): A form of sex determination where the incubation temperature determines whether the developing embryo will become male or female.

Pivotal temperature (Tpiv): The temperature that produces a population-wide 50:50 sex ratio.

Physiology: A branch of biology that studies how different parts of the body carry out chemical and physical functions.

Sex ratios: The amount of males compared to the amount of females, or vice versa.

Trachemys scripta (T. scripta): The scientific name for the red-eared slider turtle.

Yolk: The yellow-orange, nutrient-rich portion of the egg that supplies food to the developing embryo.

Learn More:

Illinois Turtles Fact Sheets (Illinois [DNR](#))

NASA's climate model [site](#)

Synopsis edited by: Rosario Marroquin-Flores, PhD (Anticipated Spring 2022), School of Biological Sciences, Illinois State University