New critical period of embryonic sex determination in sea turtles identified

November 15 2022

Sea turtles' sex is determined based on the environment, which makes them especially vulnerable to climate change. An increase in incubation temperatures could jeopardize the production of both sexes. Credit: Jay Paredes, Florida Atlantic University

Unlike humans, turtles, lizards and other reptiles—such as

crocodiles—do not have sex chromosomes. Their sex is determined based on the environment, which makes them especially vulnerable to climate change. An increase in incubation temperatures could jeopardize the production of both sexes.

Gauging primary sex ratios in these species is critical because it assesses their vulnerability under both current and future climate change constraints. While there has been great progress in sex ratio prediction, studies have been hampered due to a lack of accurate and representative regional and population sex ratio estimates. As a result, primary sex ratios calculations could be skewed.

Researchers from Florida Atlantic University, in collaboration with the Université Paris-Saclay in France, have demonstrated that the timing of key developmental process driven by temperature is vital when it comes to identifying when sex is determined for sea turtle embryos. They also are the first to compare the output of the most widely used sex ratio prediction methods to actual sex ratios from natural clutches in sea turtles.

They have developed a new way to integrate the effect of thermal fluctuations on embryonic sex determination and predict sex ratios with much better accuracy than prior models. This method measures the strength of masculinization or feminization of temperatures using novel parameters that have uncovered how temperature-sensitive sex determination works.

For the study, researchers modeled the progression of the size of loggerhead (Caretta caretta) embryos throughout incubation using an embryonic growth model that combines the thermal reaction norm for growth rate and a growth function. The thermal reaction norm represented the range of phenotypes, in this case sex ratios, which result when clutches of eggs are exposed to varying temperatures or other

varying environmental conditions. Temperatures were recorded during the total incubation for 151 loggerhead nests at six nesting beaches in Florida between 2002 and 2018.

Results, published in the journal *Ecological Modelling*, reveal that the temperature of the incubation environment could influence the sexualization of the gonads (reproductive organs) earlier than what is currently recognized. Findings show two peaks when temperature influences the sex determination—at the beginning and the end of the critical period of incubation known as the thermosensitive period of development. It is the period during development when sex is irreversibly determined and there is no turning back.

"Belly up!" A newly hatched loggerhead sea turtle on a nesting beach in southeast Florida. Credit: Jay Paredes, Florida Atlantic University

"What we observed, similar to what happens in fish, is that the temperature sensitive period takes place before the onset of the histological differentiation of the gonads, whereby they develop into either ovaries or testes," said Jeanette Wyneken, Ph.D., co-author and a professor of biological sciences in FAU's Charles E. Schmidt College of Science.

Results confirm previous concerns that the thermosensitive period, when the embryo's sex is directed to be male or female, does not match the middle third of incubation. In nature, incubation temperatures are not constant, so the rates of development are not constant.

Moreover, using the middle third of incubation duration to approximate the thermosensitive period substantially decreases the accuracy of sex ratio estimates in natural nests. These findings could be similar for other reptiles with temperature-dependent sex determination because similar molecular determinants and enzymatic mechanisms are at play.

The temperature that theoretically produces 50 percent of each sex is termed the "pivotal temperature," and the range of temperatures that produce both sexes is termed the "transitional range of temperatures."

"Given that pivotal temperatures and transitional range of temperatures are defined for constant incubation temperatures only, mean incubation temperatures cannot be considered reliable for sex ratio prediction when temperature fluctuates," said Wyneken. "In other words, a more biologically-relevant substitute must be used to predict the sex ratio of natural clutches."

To predict hatchling sex ratio, indirect methods using temperature-based proxies are particularly convenient when the species of interest is not

externally sexually dimorphic prior to the adult stage. Generally, turtles are characterized by being long-lived and late-maturing, and they are not sexually dimorphic until approaching sexual maturity—marine turtle species often take more than 25 years to become sexually mature.

"Investigating the thermal reaction norm for sexualization among reptiles with temperature-dependent sex determination will help to provide ecologically relevant hatchling sex ratio estimates, which are essential to evaluate the viability of populations in the context of climate change," said Wyneken. "Importantly, our results offer new insights into the mechanisms at play during temperature-dependent sex determination and will help to inform projections regarding the future prospects of imperiled populations worldwide."

More information: Jonathan R. Monsinjon et al, Thermal reaction norm for sexualization: The missing link between temperature and sex ratio for temperature-dependent sex determination, *Ecological Modelling* (2022). DOI: 10.1016/j.ecolmodel.2022.110119

Provided by Florida Atlantic University