THE EFFECTS OF TEMPERATURE ON PINE SNAKE POPULATION DYNAMICS

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ABSTRACT
There are many questions that arise in population dynamics, which leads to many different ways to address these questions. For our problem we addressed the effects of temperature on the population dynamics of Pine Snakes. Because the sex of some reptiles depends on a variety of factors, such as the incubation temperature of the eggs, we then had to take into account the many different ways temperature affects the population of Pine Snakes through the sex ratio.

DEVELOPING A MODEL
To first understand the relationship between temperature and the sex ratio (defined as males/females), we took a list of temperatures and used the given equation to see how the sex ratio shifted as temperatures increased, and similarly with temperature decreases. The linear equation for sex ratio is given as,

\[ R(T) \approx 0.068(T) - 0.95, \]

where \( T \) is the temperature (°C).

We next made the assumptions that there are no other snakes coming into the population or leaving, and the temperature is within a livable range. From these assumptions we used general logistic models to describe the behavior of both the male population, \( M(t) \), and the female population, \( F(t) \), as functions of time, \( t \), in years. The following are the logistic models used based on the assumptions,

\[
\frac{dM}{dt} = \frac{-\beta}{\Gamma} M(t)^2 + (\beta - \delta) M(t)
\]

\[
\frac{dF}{dt} = \frac{-\beta}{\Gamma} F(t)^2 + (\beta - \delta) F(t)
\]

with the initial conditions \( M(0) = M_0 \) and \( F(0) = F_0 \).

In this model we define \( M(t) \) and \( F(t) \) to be the number of male and female Pine Snakes, respectively, at a time \( t \), \( \beta \) to be our intrinsic birth rate, \( \delta \) to be the death rate, and \( \Gamma \) to be the maximum possible population under a certain carrying capacity, \( K = K_M + K_F \), given by \( \Gamma = \frac{\beta}{\beta - \delta} K \).

The reason for separating our population by sex is due to how the incubation temperature is shown to have an effect on the sex ratio. We then defined our population as a whole to see how the temperature affects the ratio of males to females over time given temperature changes. The population as a whole is then given by,

\[ N(t) = M(t) + F(t). \]

This then allows us to write the following logistic equation for the population as a whole,

\[
\frac{dN}{dt} = \frac{-\beta}{\Gamma} N(t)^2 + (\beta - \delta) N(t)
\]

with the initial condition \( N(0) = N_0 = M_0 + F_0 \).
Determining the Questions
Suppose due to climate change there will be larger variation in yearly temperatures. We then sought to see if our model was able to address the following questions:

1. What might happen if there are rapid changes in environmental temperatures?
2. Will the wider variations in temperatures impact the overall population dynamics of the Pine Snakes?
3. How long will it take for impacts, if any, to become noticeable?

Prediction
Based on our model we predict that if the male population were to have a 100% death rate due to some extreme cold temperature shift or even disease, our male population would then go to zero, and our overall population would then consist only of females. This would cause the population to be stable for a period of time, more than likely not reaching total population carrying capacity, and as the female population declines, the overall population would then go to zero since there would no longer be any growth.

Similarly, the expectation would also be the same in the case that the female had 100% death rate. The male population would be stable, with the overall population more than likely not hitting carrying capacity, and would decline, leaving the entire population to go to zero. This would most likely occur at a high temperature. The only exception to this expectation would be if females could asexually reproduce. Asexual reproduction would allow the female population to contribute back into the overall population with the possibility that they could produce offspring at an optimal temperature to produce at least one male hatchling, which would then cause the male population to contribute back into the total population.

Conclusion
For our model we set the initial conditions: $K = 1500$, $\beta = 0.30$, $\delta = 0.10$, $N_0 = 700$. From these initial conditions we were able to see that by manipulating the temperature, if temperatures were too cold, the females dominated the overall population compared to the males in terms of population numbers. There was very little growth for male snakes during this temperature.

Conversely, during extreme heat waves, the males dominated the population in terms of numbers, which in the long run could lead to an extinction event if all of the females were to die. This could also be expected during a cold weather season where females dominated, assuming they do not asexually reproduce. The impacts between male and female populations in extreme temperatures were noted almost immediately, as in there was very little growth for each during these weather extremes. If rapid changes did occur during the egg incubation period, we could see a shift in population dynamics as these hatchlings aged and the older males and females died off.
REFERENCES

