Bio4009 : Projet de recherche/research project

Is emergence after hibernation of the black ratsnake (Elaphe obsoleta) triggered by a thermal gradient reversal?

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18 janvier 2010

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ABSTRACT

For temperate ectotherms, the timing of hibernation is essential because of their short active period; hence the necessity for a reliable trigger of emergence. I used telemetry to monitor body temperatures inside the hibernacula of black ratsnakes (*Elaphe obsoleta*) during hibernation, and fenced the hibernacula to be able to catch the snakes upon their emergence. We found that there is in fact a reversal of the vertical thermal gradient between the inside and outside of the hibernacula, and it is, in some cases, correlated with the peak of emergence for that hibernaculum. However we cannot conclude that this reversal is the major cue for emergence; it is more likely a combination of several cues (external and internal) that triggers emergence. Moreover, we found that there was a negative relationship between mean temperature and median emergence date in the different hibernacula, but this relationship was not significant.

INTRODUCTION

In north temperate regions, reptiles have an active period of approximately 5 months, during which they have to reproduce, grow and build energy reserves for the oncoming winter that is spent in hibernation. Given the time constraints reptiles face at the northern limit of their distribution, one would expect selection to have favored individuals that make the most of the few favorable months. For most reptiles, hibernation is triggered by a change in temperatures and day length (Gregory, 1982).

Since their active season is so short, they will want to emerge from hibernation as soon as possible, to allow for more time outside the hibernaculum, to be able to reproduce, grow, and accumulate energy for the upcoming hibernation period. An early emergence for males can also result in a better reproductive success (Olson *et al*, 1996; Diaz *et al*, 1994 Veiga *et al*, 2001).

Although it has significant advantages, early emergence can be costly: low temperatures can result in death, or make thermoregulation harder for ectotherms, enhancing predation risks (Veiga *et al*, 2001) if snakes get out of the hibernaculum too early. Therefore, because of these costs, the timing of emergence has to be a compromise between the need to emerge as early as possible and to avoid deathly temperatures of early spring. Thus, this compromise should have been optimized by selection, and snakes should use reliable cues allowing them to emerge at the right time.

The black ratsnake (*Elaphe obsoleta*) is mostly distributed in the east of the United States, but it ranges as far north as eastern Ontario. Like other temperate zone ectotherms, black ratsnakes in Ontario must spend the winter in hibernation, from late October to mid-April (Blouin-Demers *& al*, 2000), which is almost 2 months longer than the more southern populations. Since they have a shorter active period than the snakes of the southern populations, they are on an even tighter schedule, making the timing of hibernation and emergence essential.

The first aim of this study is therefore to determine whether temperature can act as an environmental cue to trigger spring emergence for the black ratsnake (*Elaphe osboleta*). We know that emergence is based on a climatic cue for the prairie rattlesnake (Jacob *et al*, 1980; Sexton *et al*, 1981), the painted turtle (Crawford, 1991), and the sixlined racerunner (Etheridge *et al*, 1983). It has also been suggested that a change in temperature gradient could cause the spring emergence in black ratsnakes in a study by Sexton and Hunt (1980), but no evidence of this was found in a later study that concluded that emergence was probably triggered by an internal cycle (Weatherhead, 1989). This last study was however conducted over one year only, with less than 10 individuals, and therefore had low power. That is why we propose to redo that study, following the hypothesis that spring emergence is triggered by a reversal of the vertical thermal gradient inside the hibernacula. We then predict that the snakes should emerge from hibernation when the temperature inside the dens starts to climb.

In a study by Blouin-Demers *et al* (2000), we learn that emergence date is dependant of the hibernaculum. The second aim of this study was therefore to try and explain the variation between the emergence dates of the hibernacula: is the late median emergence of certain hibernacula due to colder mean temperature during this period?

METHODS

Location and study species

We studied black ratsnakes at the northern extreme of their distribution at the Queen's University Biological Station (QUBS), located 100 km south of Ottawa, Ontario, Canada.

Data collection

We based our protocol on the methods used by Weatherhead (1989). At first, adult snakes were caught opportunistically, implanted with a radiotransmitter and followed to their hibernaculum in the autumn. Black ratsnakes hibernate in groups

(Blouin-Demers *et al*, 2000), so if we fenced the hibernacula, more snakes could be captured upon their emergence from hibernation, and brought to the lab to be processed; that way, we were able to identify more than 20 hibernacula across QUBS.

To process the snake, we measure, sex, weight and identify them with a PITtag, note the emergence date (capture date) and capture location. We captured the snakes every spring since 1996, processed them and brought them back at the capture location; some individuals were surgically implanted with radiotransmitters, in the body cavity, and followed during the transmitter's life time (18 months). The transmitter's pulse rate decrease with temperature: it was therefore monitored each time an implanted snake was located. The manufacturer provided us with calibration data for each transmitter (pulse at different temperatures ranging from 0.3 to 40°C). We adjusted a polynomial curve, in JMP stats program, with these data for each transmitter, and derived an equation from it, allowing us to determine the body temperatures of the snakes from the pulse of their transmitter. Since snakes are ectotherms, the body temperatures calculated can be considered as the hibernacula's temperature during hibernation. The implanted snakes' temperatures were taken at the hibernacula during hibernation almost once a month, and almost every other day during the emergence period. If a snake died during hibernation, it would not emerge in the spring and the transmitter would stay in the hibernaculum, allowing us to monitor the temperature in the hibernaculum during the emergence period.

Data analysis

To answer the question of what could trigger spring emergence of the black ratsnake, I used the temperature data of snakes that died in the hibernacula during hibernation to make a graph of temperature along the emergence period. Then, on the same graph, I did a bar graph of how many snakes would emerge during a 5-day period.

To answer the second question, I calculated the mean temperature of each hibernaculum for a given year, from April to May included (emergence period), and the median emergence date converted into Julian days. I used the median emergence date instead of the mean because it is a better measure of the central tendency for skewed distributions like the one we have here. I produced a graph of mean temperature versus median emergence date for each year and looked at the correlations.

RESULTS

Reversal of the temperature gradient

Although we implanted more than 80 snakes with radiotransmitters since 1996, only 8 of them died during hibernation while they were implanted. Therefore, we have temperature data during the emergence period for only 7 hibernacula, for the years 1997, 1998, 1999, 2001 and 2002; we have data for the hibernacula "Old Rideau" and "Wagon Loop" for 2 years, and the other ones were used for one year only (*F*ig. 1).

Except for the hibernaculum "Lower Rock", where the temperature is declining until the beginning of May and then starts to climb (Fig. 1), we note a temperature increase starting in the beginning of April in all of our hibernacula. The temperature even seems to be declining until then, for the hibernacula "Curtis" (Fig. 1), "Opinicon" (Fig. 1), "Two Island" (Fig. 1), and "Warner" (Fig. 1).

At "Old Rideau" in 1997, the most snakes emerged around 30 April (Fig. 1). In 1998, the peak of emergence was around 22 April at "Old Rideau" (Fig. 1) and "Two

Island" (Fig. 1) and 27 April at "Wagon Loop". In 1999, it was around 24 April at "Opinicon" (Fig. 1) and 30 April at "Lower Rock" (Fig. 1) and "Warner" (Fig. 1). Finally, the emergence peak was around 22 April in 2001 at "Wagon Loop", (Fig. 1), and in 2002 at "Curtis" (Fig. 1).

Mean temperature vs. median emergence date

We calculated the mean temperature and median emergence date for 10 hibernacula over 7 years. There was a non-significant relationship between temperature and emergence date (Fig. 2, r = -0. 52, p = 0.48).

<u>DISCUSSION</u>

Reversal of the temperature gradient

The increase in temperature inside the hibernacula is interpreted as a reversal of the temperature gradient inside the den: in the winter, temperatures were colder outside than inside the den, therefore temperature was decreasing inside the den. But in the spring, ambient temperatures increase, so that they become higher than the temperatures inside the hibernaculum: we then witness the reversal of the vertical temperature gradient. This reversal of the temperature gradient often seems to coincide with the peak of emergence for the given year. The hypothesis proposed by Weatherhead (1989) was that an endogenous rhythm would trigger emergence after a fixed time in hibernation: this would mean that one snake would hibernate for a certain number of days, constant over the years, which would need to be verified. Moreover, the emergence date of one individual varies over the years (Blouin-Demers *et al*, 2000): could it be due to temperature variations? This would then rule out the hypothesis of an endogenous rhythm. Without being able to prove it, the reversal of the thermal gradient seems a better candidate for triggering emergence than it did in the study by Weatherhead (1989).

Since the timing of emergence is so important for the individuals, it would be surprising if it were based on only one cue. Emergence is more likely triggered by a combination of several factors, probably including a reversal of the temperature gradient. In fact, in the only cues were climatic cues, the emergence could occur too late for the snakes to have a decent active period. For example, at "Lower Rock" in 1999 (Fig. 2), if the reversal of the thermal gradient was the only trigger, snakes would have emerged around the 15^{th} of May, which is relatively late. Since spring temperatures fluctuate a lot; this could be the reason for the late reversal at this hibernaculum (combined with the location and structure of the hibernaculum). Therefore, temperatures inside the den are not perfect indicators of the temperatures outside; that is why snakes could need more than that climatic cue to trigger their emergence.

Mean temperature vs. median emergence date

We observe a negative relationship between temperature and emergence date, which means that colder hibernacula would have a later median emergence date than warmer ones. This would explain the variations in emergence date between hibernacula; however, this relationship is not significant, with our current sample size. We therefore cannot conclude that the variation between hibernacula is due to temperature variations.

The differences in temperature between the hibernacula are most certainly due to differences in the internal structure of the den (Weatherhead, 1989). We used the mean temperature during the emergence period (April to May included) instead of the mean temperature during the whole hibernation period because we assumed that the variations in temperature between the hibernacula during the cold months (December to Mars) did not have an effect on emergence. This is because we assume that the difference in the internal structure of the dens will affect the rate of the variation (how fast the temperature decreases or increases inside the hibernacula), and not the temperature itself, and that it why we only considered the period of time when temperatures are supposed to be increasing. It would then be interesting to test this assumption, and see if maybe winter temperatures can affect the spring emergence.

ACKNOWLEDGEMENTS

I am grateful to Dr. Blouin-Demers for collecting most of the telemetry data, for his helpful guidance throughout the project and for funding the research, and to Queen's University for the use of the biological station. I also acknowledge Gregory Bulté and Patrick Weatherhead for laboratory assistance and advices, and Antoine Morin for teaching me statistics.

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APPENDIX (FIGURES)

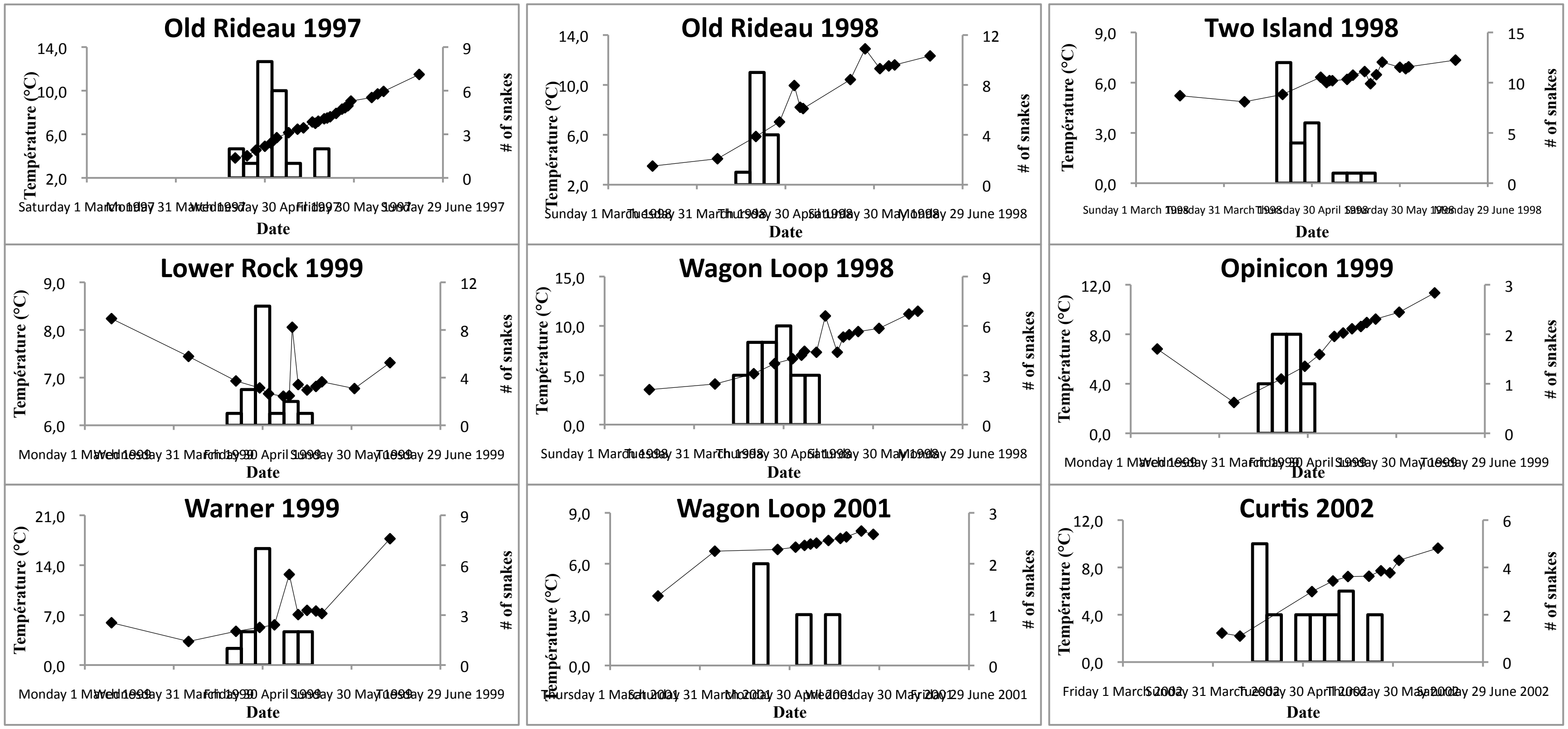

Figure 1: Temperature of one female black ratsnake (412c563d69) that did not emerge during spring emergence at the hibernaculum "Warner" in 1999; each point represents a single measurement. The bars represent the number of different individuals that emerged that spring from that hibernaculum.

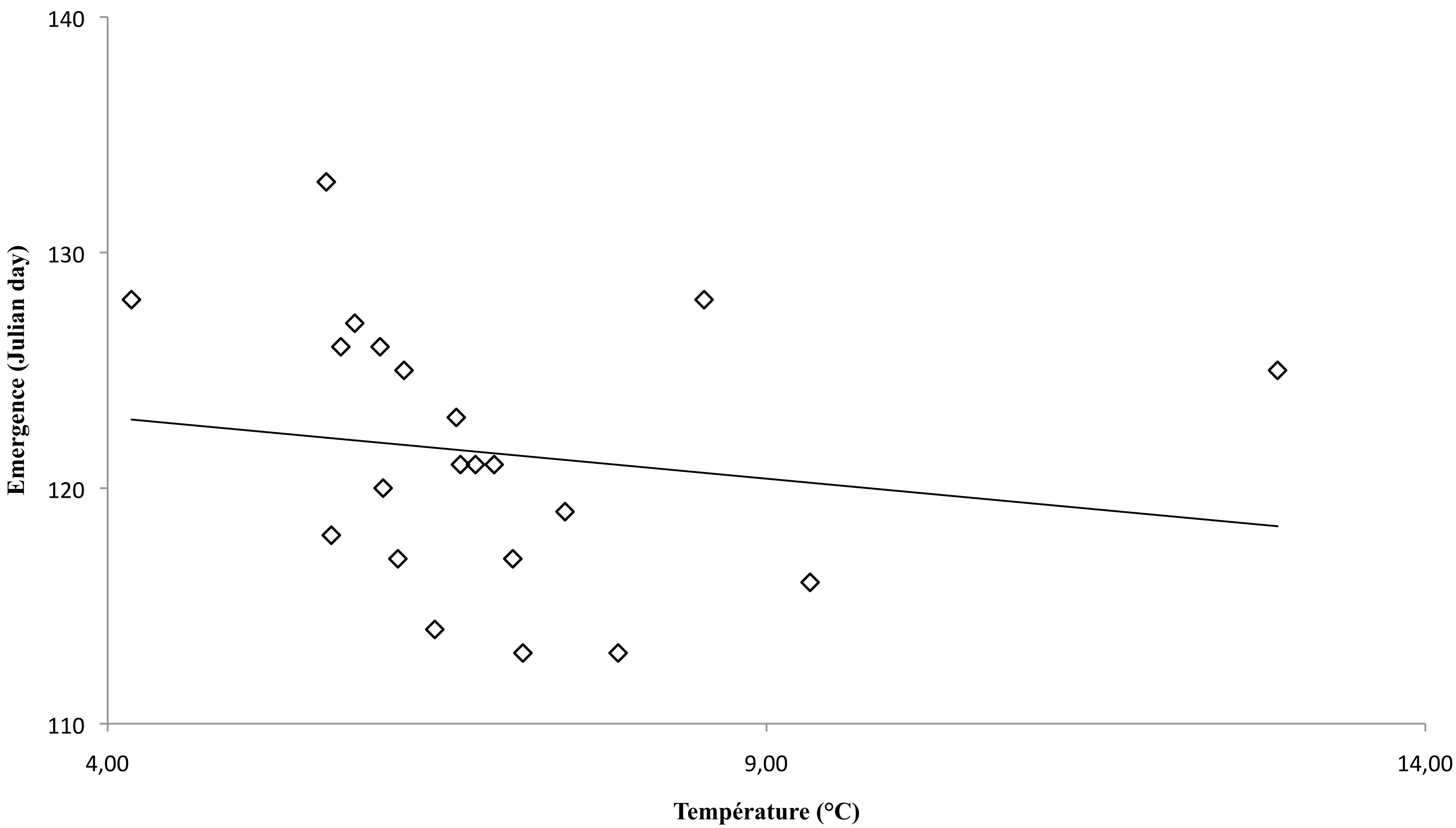

Figure 2: Relationship between the mean temperature of a hibernaculum and the median emergence date for that hibernaculum. Each point represents the data of one hibernaculum for one year.