Condition-dependence of Defensive Tail Displays in Common Garter Snakes *(Thamnophis sirtalis)*

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Abstract

Individual snakes can exhibit a diversity of antipredator responses including crypsis, flight, and a variety of stereotyped behavioral reactions to predators at close range. Among these responses are behavioral differences in the movement (e.g., waving or wiggling) of a conspicuous tail by an otherwise cryptically colored snake. Defensive tail displays may disorient a predator, divert attack to the tail, act as a warning signal, or serve no function at all. The use of tail displays in snakes may also depend on current physiological investment into color production and body size, which can affect locomotor ability to escape predators. The purpose of this study was to determine if variation in tail color is related to the defensive tail behavior exhibited in Common Garter Snakes (*Thamnophis sirtalis*) when subject to a sudden tactile stimulus. We also analyzed potential relationships between tail coloration, mass, and circulating concentrations of testosterone, to determine if conspicuous tail morphology is condition-dependent. Here, relative tail orange coverage is significantly related to defensive tail behavior and also yields significant negative correlations with mass and testosterone concentrations. This suggests conspicuous tail displays in *T. sirtalis* to be a size-dependent response to predation, as mediated by testosterone. The prevalence of this defensive behavior in relatively smaller snakes may function as a diversion of attack to the tail while larger snakes instead exhibit greater locomotor capacity to escape predation.

Introduction

- Individual snakes can exhibit a diversity of anti-predator responses including crypsis, flight, and a variety of stereotyped reactions to predators at close range.[1]
- Among these responses are behavioral differences in the waving or wiggling of a conspicuously colored tail by an otherwise cryptically colored snake.[1]
- Defensive tail displays may disorient a predator, divert attack to the tail, act as a warning signal, or serve no function at all.[2]
- Functional use of tail displays in snakes may depend on current physiological investment into life history characteristics related to growth and survival.
- Greater tail color investment for defensive displays may occur when immediate body size limits locomotor ability to escape predation.[3-4]
- The purpose of this study was to determine if variation in orange tail coloration is indicative of defensive tail behavior exhibited in Common Garter Snakes (*Thamnophis sirtalis*), and to what extent this relationship is condition-dependent.

Figure 1. Adult male Common Garter Snake (*Thamnophis sirtalis*).

Hypothesis

We hypothesized that tail color coverage indicates defensive tail display behavior in male Common Garter Snakes, as mediated by differences in physiological condition.

Methods & Materials

Field Capture and Measurements

- During Spring 2014, 39 adult male garter snakes were caught at two locales in Logan, UT, USA.
- Body mass was measured using a digital scale, and snout-vent length was measured using a standard metric ruler.
- Blood samples were collected for analysis in the lab.

Blood Analysis

- Testosterone (Radioimmunoassay)

Behavior Analysis

- Snakes were tactile stimulated on a 2-meter track to determine flight or defensive behavior.

Figure 2. A 2-meter racetrack equipped with infrared sensors.

Tail Coloration Measurements

- Individual tails photographed with metric ruler.
- Relative tail color coverage calculated in ImageJ.

Figure 3. ImageJ interface used to analyze aspects of coloration.

Statistics

- (n = 39 snakes)
- ($p < 0.05$) = statistically significant

Binary Logistic Regression / Receiver Operating Curve

Dependent Variable: Defensive Tail Display (Yes / No)

Independent Variable: Relative Color Coverage (%)

Multiple Regression

Dependent Variables:

- Relative Color Coverage (%)

Independent Variables:

- Mass
- Testosterone

Results

- Relative color coverage significantly predicts about 75% of defensive tail behaviors (Fig. 4; p = 0.011, AUC = 0.752).
- For every 19% (B = 0.189) increase in color coverage, snakes are about 1.2 (Exp(B) = 1.21) times more likely to exhibit a defensive tail display, with about 20% of variation in the behavior explained by variation in orange coloration (Cox & Snell r^2 = .199).
- Color coverage is significantly, negatively related to body mass (Fig. 5; p = 0.018, r^2 = 0.124) and significantly, negatively related to circulating testosterone (Fig. 6; p = 0.0049, r^2 = 0.192).

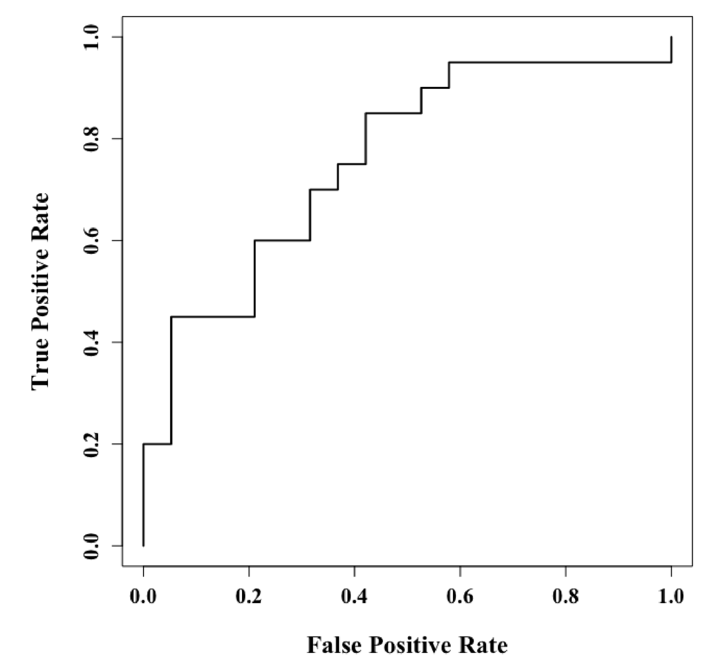

Figure 4. Potential to predict defensive tail behavior with area under the receiver operating characteristic curve (AUC = 0.752), measured by tail color coverage in Common Garter Snakes.

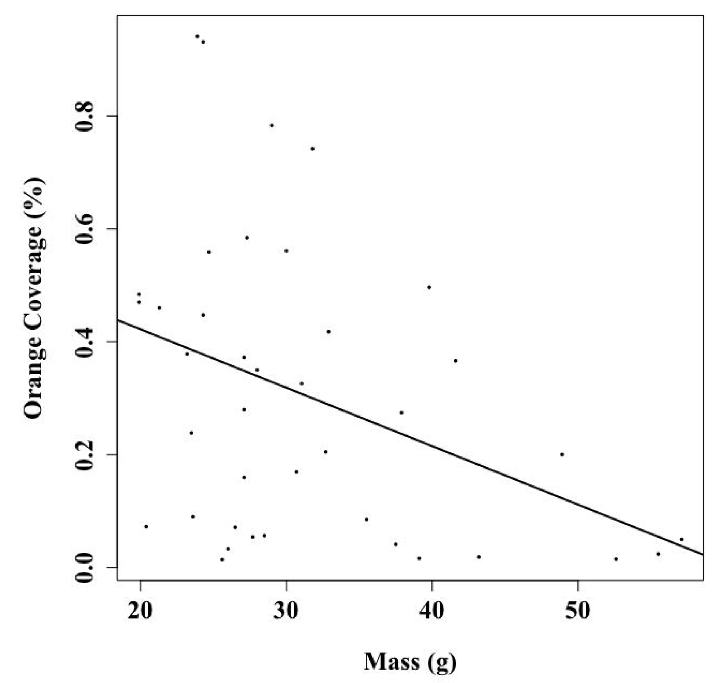

Figure 5. Orange color coverage of tails in male Common Garter Snakes with respect to body mass (p = 0.018, r^2 = 0.124).

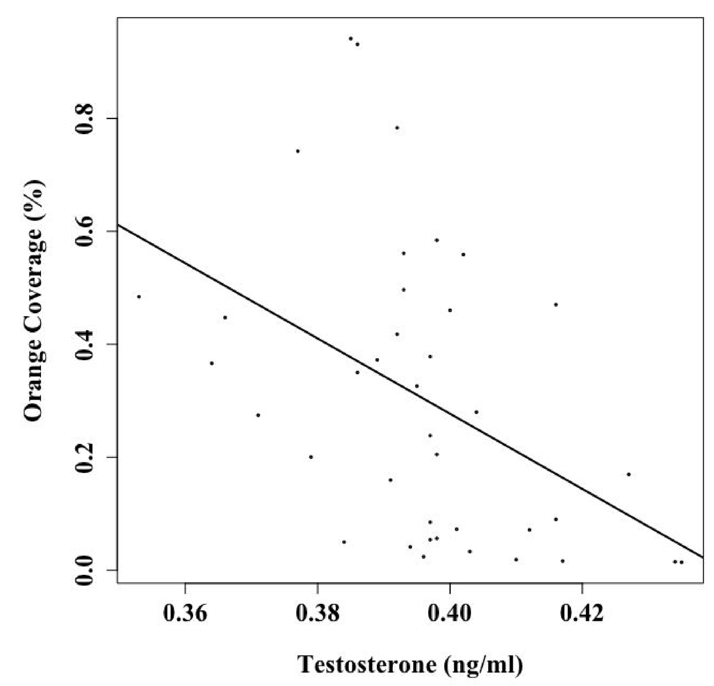

Figure 6. Orange color coverage of tails in male Common Garter Snakes with respect to testosterone levels (p = 0.0049, r^2 = 0.192).

Discussion

- Our hypothesis that defensive tail display behavior in male Common Garter Snakes is condition-dependent was supported.
- Defensive tail behavior is significantly related to relative tail color coverage of snake tails. Moreover, variation in color coverage is negatively related to body mass and circulating levels of testosterone.
- Based on these findings, we suggest that snakes of smaller body size invest more in orange tail coloration to compliment the function of defensive tail behavior.
- The prevalence of tail defensive behavior and conspicuous coloration may function as a diversion of attack to the tail when the prospects of escaping predation are limited by locomotor capacity. This would leave the head free to gain a mechanical advantage and escape.[5-6]
- Size-dependent variation in defensive responses have also been found in Cottonmouths (*Agkistrodon piscivorus*).[7] Here, increasing body size leads to declines in anti-predator behaviors.
- Differences in defensive behavior, color expression, and body size may be mediated by testosterone levels as this hormone is known to regulate development and maintenance of these traits.[8-9]
- Increases in testosterone levels have also been positively correlated with frequency of defensive behaviors in Common Garter Snakes (*Thamnophis sirtalis*).[8]

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Acknowledgments

We would like to thank Dr. Edmund Brodie for providing the racetrack for this experiment. We would also like to thank all of the French lab undergraduates who assisted with the field work and lab analyses.