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FECAL PELLET MASS AS A FUNCTION OF BODY SIZE, COLOR MORPH, AND SEASON IN *PLETHODON CINEREUS* (GREEN, 1818) (AMPHIBIA: PLETHDONTIDAE)

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ABSTRACT: In plethodontid salamanders, fecal pellets have a variety of behavioral functions related to chemical communication. We examined how fecal pellet mass in the Eastern Red-backed Salamander (*Plethodon cinereus*) varies with body size, color morph, and season. Fecal pellet mass increased with salamander size. Striped *P. cinereus* produced heavier fecal pellets than unstriped *P. cinereus*. Fecal pellet size tended to be greater in the spring than in the fall. Our results suggest further investigations of the factors governing fecal pellet size in plethodontid salamanders is warranted.

Key Words: Caudata; Eastern Red-backed Salamander; Feces; Ohio; Plethodontidae

INTRODUCTION

Fecal pellets can serve a variety of behavioral functions in plethodontid salamanders. Fecal pellets may be used by females to assess the quality of potential mates (Mathis, 1990a; Jaeger and Wise, 1991), potentially through assessment of the quality or composition of the male's diet (e.g., Walls et al., 1989; Chouinard, 2012). Fecal pellets may be used to mark territories (Jaeger, 1986; Mathis, 1990a; Simons and Felgenhauer, 1992; Anthony, 1993). Fecal pellets can also be used to identify conspecifics and heterospecifics and the sex of the individual (Ovaska and Davis, 1992). In addition, they may be used as a source of information about the availability and quality of prey in the environment (Karuzas et al., 2004).

Given the potential importance of fecal pellets in plethodontid salamander biology it is surprising that little is known about the factors that affect the size of the fecal pellet. Mathis (1990a) found that fecal pellet volume was not related to female body size but was in males only if males were presented with female chemical cues. In addition, Mathis (1990a) found that male and female *P. cinereus* can increase the size of the fecal pellets they produce in response to a resident male of similar size, but not a resident female. This finding suggests that the size of a fecal pellet may be manipulated in social situations, perhaps by altered passage rates (Mathis, 1990a), indicating that fecal pellet size may be important in such communication, but this has not been examined.

The striped and unstriped morphs of *P. cinereus* show a variety of differences in their ecology and physiology. Of particular relevance to our study, they differ in diet (Anthony et al., 2008; Paluh et al., 2015; Stuczka et al., 2016), aggression and territory holding ability (Reiter et al., 2014), and metabolic rate (Moreno, 1989; Petruzzi et al., 2006). Given that differences in these ecological and physiological characteristics differ between color morphs in *P. cinereus*, it seems likely there may be differences in fecal pellet size. We examined variation in fecal pellet mass in Eastern Red-backed Salamanders (*P. cinereus*) as a function of body size, color morph (striped vs. unstriped), and season (fall vs. spring).

MATERIALS AND METHODS

We collected *P. cinereus* from under natural and artificial cover objects on the Denison University Biological Reserve in fall 2019 (7 October: 3 unstriped, 8 striped; 11 October: 1 unstriped, 16 striped; 18 October, 7 unstriped, 12 striped; 24 October: 5 unstriped, 9 striped) and spring 2020 (29 March: 6 unstriped, 10 striped; 3 April: 3 unstriped, 13 striped). Within 24 h of capture, we measured snout-vent length (SVL), recorded color morph (striped or unstriped), and placed salamanders in individually marked 150mm diameter petri dishes with filter paper saturated with aged tap water for 24 h. At the end of 24 h we collected and weighed any fecal pellet produced (wet mass to nearest 0.001 g). Thus we used only a single fecal pellet per individual. We did not feed

Table 1. Mean (± 1 S.E.) and least squares mean (LSM) (± 1 S.E.) fecal pellet mass of striped and unstriped *Plethodon cinereus* in the fall and spring. *n* is given in parentheses.

Color morph	Fall		Spring	
	Mean	LSM	Mean	LSM
Striped	0.014 ± 0.003 g (23)	0.016 ± 0.002 g (23)	0.018 ± 0.003 g (7)	0.020 ± 0.004 g (7)
Unstriped	0.008 ± 0.002 g (8)	0.002 ± 0.004 g (8)	0.012 ± 0.003 g (5)	0.011 ± 0.004 g (5)

salamanders during the period of captivity so all fecal pellets reflected their diet and prey consumption prior to collection (see Acord et al., 2013).

We used a two-way ANCOVA to compare fecal pellet mass among color morphs and seasons with SVL as a covariate. We did not include the interaction terms with SVL in the final model since none were statistically significant (all P > 0.05), indicating the relationship between SVL and fecal pellet mass did not differ between morphs or seasons (i.e., the slopes were homogeneous). We used JMP Pro 15.1 (SAS Institute, Cary, NC, USA) to conduct statistical analyses, and an a-value of 0.05 for statistical significance.

RESULTS

We obtained a total of 43 fecal pellets, 31 in fall (23 striped, 8 unstriped), 12 in spring (7 striped, 5 unstriped). Striped *P. cinereus* produced larger fecal pellets than unstriped *P. cinereus* (Table 1; $F_{1,38} = 8.98$, $p = 0.0048$) independent of body size. Fecal pellet mass tended to be greater in the spring than in the fall (Table 1; $F_{1,38} = 3.2$, $p = 0.084$). There was no significant interaction between season and color morph (Table 1; $F_{1,38} = 0.33$, $p = 0.57$). Fecal pellet mass increased with SVL ($F_{1,38} = 11.7$, $p = 0.0015$; Fecal pellet mass = -0.008 + 0.006SVL).

DISCUSSION

Fecal pellet mass increased with body size in *P. cinereus*. Mathis (1990a) found that the volume of a fecal pellet was not related to the body size in female *P. cinereus* but increased with SVL in male *P. cinereus* under some conditions. One possible explanation for greater fecal pellet mass with body size is that larger salamanders can eat larger prey (e.g., Raimondo et al., 2003) and so might produce larger fecal pellets. In addition, prey abundance in *P. cinereus* territories was positively correlated with the salamander's body size (Gabor, 1995), thus they may consume more prey and thus produce larger fecal pellets. Given that fecal pellet mass increases with SVL, individual salamanders may be able to use the size of the fecal pellet as a cue to assess the body size of another individual. This assessment would possibly be in addition to using fecal pellets as a chemical cue to the quality of an individual salamander (e.g., Walls et al., 1989; Jaeger and Wise, 1991). Because body size is frequently important in the outcome of territorial and aggressive encounters in *P. cinereus* (Mathis, 1990b, 1991; Mathis and Simons, 1994; Townsend and Jaeger, 1998), being able to assess the size of a potential opponent using fecal pellet size could be a useful strategy. We are unaware of any investigations into the ability of salamanders to differentiate fecal pellet size but such experiments might be worthwhile given their apparent use as territory markers. However, it does appear that *P. cinereus* can adjust the size of their fecal pellet in response to the perceived size of an intruder (Mathis, 1990a), suggesting the size of a fecal pellet may indeed be used as a territorial signal in *P. cinereus*.

Striped *P. cinereus* had greater fecal masses than unstriped *P. cinereus*. The difference in fecal pellet mass between color morphs may reflect differences in the quality and quantity of prey they consume. For example, the diet of striped *P. cinereus* is made up of higher quality prey than that of unstriped *P. cinereus* (Anthony et al., 2008), and the territories and diets of striped *P. cinereus* often contain more and higher quality prey (Anthony et al., 2008, 2017; Paluh et al., 2015). However, the difference in diet between the two color morphs in *P. cinereus* can vary among populations, with some populations showing a difference and others not (Hantak et al., 2020).

We found that fecal pellets tended to be heavier in the spring than the fall, but not significantly at an α-value of 0.05. The possible difference in fecal pellet mass between spring and fall may be due, at least in part, to potential differences in the quantity of prey and the composition of prey in diets between the seasons. For example, prey volume in *P. cinereus* varied among seasons, with somewhat lower prey volumes in the fall (September-October) than spring (May-June) (Maerz et al., 2005). In addition, the species of ant found in the diet of *P. cinereus* shifts between the spring and the fall (Paluh et al., 2015).

Our study demonstrated that fecal pellet mass varied as a function of body size and colour morph, and possibly between seasons. Given the importance of fecal pellets in various aspects of the behavior of *P. cinereus* and their ecosystems, we encourage more investigations into the factors that influence fecal pellet size in *P. cinereus* and other plethodontids.

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