

TAIL-COILING IN RINGNECK SNAKES: FLASH DISPLAY OR DECOY?

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Abstract. Although tail-coiling behavior has been noted and well described in the literature, the evolutionary drive for this trait's expression has remained unknown. The two most obvious hypotheses explaining tail-coiling in ringneck snakes (*Diadophis punctatus*) are that it is a startle display or it functions as a decoy to misdirect predator attack. We compared the frequency of tail injuries in 200 *D. punctatus* to the frequencies in 145 *Carphophis amoenus*, 60 *Storeria occipitomaculata*, and 61 *Storeria dekayi*. The three species used for comparison are not known to perform tail-coiling. Tail damage occurred in 9.5% of *D. punctatus*, 0.7% of *C. amoenus*, 3.3% of *S. occipitomaculata*, and 6.6% of *S. dekayi*. There were significantly more instances of tail damage in *D. punctatus* than in the other three species ($\chi^2 = 13.345$, $df = 3$, $P < 0.01$). The frequency of tail damage in male, female, and juveniles was not significantly different ($\chi^2 = 0.45$, $df = 2$, $P < 0.80$). The presence of significantly more tail damage in *D. punctatus* than the other three species suggests that tail-coiling might play a role in maintaining this frequency. If this behavior were a startle display, *D. punctatus* should not possess any more incidences of tail damage than the other species. Because *D. punctatus* does possess more, we must accept the decoy mechanism as an appropriate explanation for tail-coiling behavior.

Key Words. Flash display; Decoy mechanism; Ringneck snakes; *Diadophis punctatus*; Predation; Defense; Tail injuries.

The ringneck snake (*Diadophis punctatus*) is a common but secretive small snake of woodlots, field borders, and rocky slopes throughout much of North America (Conant and Collins 1998). When encountered, *D. punctatus* frequently positions its tail in a tight coil and inverts it to reveal its brilliant red-colored ventral surface. The earliest descriptions of this behavior were by Ditmars (1907) and Grinnell (1908). The behavior was mentioned several times by Blanchard (1942). Davis (1948) further described the behavior indicating that the head was hidden

under the body during performance. In around 14% of attacks, the behavior advances into death feigning reminiscent of that expressed by *Heterodon* (Gehlbach 1970), though we have never observed this elaboration in either Arkansas or Illinois. Ringneck snakes also release a musky contrivance of liquid feces and uric acid that is smeared upon its attacker (Ernst and Barbour 1989; Fitch 1975). Expression of tail-coiling varies geographically and appears to be limited to the subspecies with red venters (Meyers 1965). Ditmars (1910) hypothesized that this behavior was an attempt to intimidate an enemy, whereas Grinnell (1908) and Gehlbach (1948) suggested it might be aposomatic in nature. This flash might also startle the predator, allowing the snake time to escape (Fitch 1975). Fitch (1975) observed 100 incidences of predation on *D. puncta-*

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tus comprising 35 events by *Agkistrodon contortrix*, 25 by *Buteo jamaicensis*, 15 by *Coluber constrictor*, 13 by *Buteo platypterus*, two by *Lampropeltis triangulum*, and one each of *Bubo virginianus*, *Crotalus horridus*, and *Rana catesbeiana*.

In the laboratory, 75% of 100 snakes tested performed some variation of tail-coiling while in the field 96% of 100 snakes performed the behavior (Fitch 1975). Smith (1975) observed tail-coiling in 60% of 80 snakes tested, and tail-coiling becomes less prevalent as length of the snake increases. This behavior diminishes as the animals become conditioned to handling and captivity.

Snake tail displays can function as follows (Greene 1973): (1) they have no function; (2) they are intraspecific signals with respect to territory or courtship; (3) they serve to attract prey; (4) they act as a flash (startle) displays; (5) they are decoys diverting attack from the head to the tail; (6) they are aposomatic or intimidating; or (7) they serve some other unknown purpose. Tail displays may function in more than one of these areas depending on the situation (Greene 1973).

There is no evidence of intraspecific signaling through tail-coiling between the sexes or during male-male contest (Fitch 1975), and no significant difference in the frequency of tail-coiling behavior between the sexes (Smith 1975). No observations of tail-coiling during feeding have been reported. There is only meager isolated observations providing evidence this species is mildly venomous (Gehlbach 1974; Henderson 1970; Shaw and Campbell 1974); overall, it is considered harmless (Ernst and Barbour 1989). The musk it smears on enemies is fairly innocuous. The suggestion that tail-coiling in ringnecks has no function is evolutionarily illogical. The motionless pose combined with the bright color display provides an easy target for predators. For this reason there should be strong selection against this kind of behavior if it had no tactical value. This leaves two potential hypotheses for tail-coiling in ringneck snakes. The behavior may act as a startle display, in which the predator would hesitate allowing the snake to escape, or it may act as a decoy, causing the adversary to attack and break off or damage the tail while the rest of the snake finds refuge. If a predator grasps the tail, ringnecks might be more capable of anchoring themselves in a hole or around debris. This could allow this snake to pull itself from the grasp of the predator. There is no current evidence to support

either explanation for tail-coiling in *D. punctatus* (Ernst and Barbour 1989).

Greene (1973) pointed out that determination of tail display functions must include information about tail damage frequency. If this behavior functions as a startle display, we would expect incidences of tail damage in *D. punctatus* to occur either as often or less often than similar snake species. If tail-coiling functions as a decoy mechanism, we might expect frequencies of tail damage in *D. punctatus* to exceed those of similar species. While references to tail damage in *D. punctatus* do occur in the literature (Blanchard 1942; Fitch 1975), no study has attempted to quantify this information or use it to help explain the purpose of tail-coiling in *D. punctatus*.

MATERIALS AND METHODS

Carphophis amoenus, *Storeria occipitomaculata*, and *Storeria dekayi* were selected for comparison to *D. punctatus* because of their similar size and with rationale as follows: (1) *Carphophis amoenus* is probably more fossorial than *D. punctatus*, whereas *S. occipitomaculata* and *S. dekayi* are probably more terrestrial; (2) *Carphophis amoenus* and *S. occipitomaculata* share the red venter with *D. punctatus*, and *S. dekayi* lacks this trait; and (3) none of the other three snakes utilize tail-coiling when captured.

The number of damaged tails was tallied from Arkansas specimens deposited in the Arkansas State University Museum of Zoology herpetological collection. In all species, specimens with damage indicative of road kill or capture technique were placed in the no-damage category unless damage on the tail was obviously healed and not caused by road/collection injury. Because of the questionable ability to identify between regenerated and original tails, regenerated tails were included as undamaged. In specimens where the tail damage was potentially caused by formalin injections, the individual was deemed undamaged. *D. punctatus* were sexed by cloacal probing and dissection.

Frequency of tail damage was analyzed using Chi square tests. Tail damage was examined between all four species, and between the males, females, and juveniles of *D. punctatus*.

RESULTS

Diadophis punctatus had tail damage in 9.5% (19/200) of the specimens examined (Table 1). In

TABLE 1. Frequency of tail damage in four species of snakes from Arkansas.

Species	Number with Tail Damage	Number Undamaged	Total
<i>Diadophis punctatus</i>	19	181	200
<i>Carphophis amoenus</i>	1	144	145
<i>Storeria dekayi</i>	4	57	61
<i>Storeria occipitomaculata</i>	2	58	58
Total	26	440	464

comparison, *C. amoenus* had 0.7% (1/145), *S. occipitomaculata* had 3.3% (2/60), and *S. dekayi* possessed 6.6% (4/61). There was a significant difference in frequency of tail damage among all four species ($\chi^2 = 13.345$, $df = 3$, $P < 0.01$) but there was no significant difference between *S. occipitomaculata*, *S. dekayi*, and *C. amoenus* ($\chi^2 = 4.38$, $df = 2$, $P < 0.10$). The frequency of tail damage between male (12/111), female (5/48), and juvenile (4/41) *D. punctatus* were not significantly different ($\chi^2 = 0.45$, $df = 2$, $P < 0.80$). Tail damage varied from missing tails to tails with apparent bite-marks on the lateral flanks.

DISCUSSION

Diadophis punctatus possessed more tail damage than the other three species examined, and there were no differences in tail damage frequencies between the other three species. This suggests that tail-coiling is employed as a decoy, displacing predator attack to the tail and allowing the snake to seek refuge. The lack of difference in tail damage frequencies between the other three species suggests tail-coiling is the primary contributor this damage and not the degree of terrestriality, belly coloration, or potentially employed alternative, anti-predator strategies in *D. punctatus*.

This behavior is a fairly risky tactic compared to other anti-predator strategies that might be employed. Predators do cause damage to snakes when they perform tail-coiling displays as evidenced by our results. Damage to and loss of a tail can be a significant cost to the snake. During breeding male water snakes are known to vibrate their tails against the female, possibly having some stimulating action to her (Gillingham 1987). If a male’s tail is missing, the individual may not be capable of initiating caudocephalic waves during the “tactile-chase” (Phase 1) of courtship (Gillingham 1987).

This may result in a reduced or nil reproductive capacity through such behavioral inhibition. Whether male *D. punctatus* utilize the tail during courtship is unknown, and Fitch (1975) did not observe a continuous courtship ritual to make a determination.

Tail damage and loss also requires the snake to invest resources in repair of the damaged tissue, regrowth, and defense against invading pathogens. The odor from blood during the battle is also a potential source of later predation since an attacker could follow this scent trail to find the now weakened victim. There is no evidence that *D. punctatus* autotomizes its tail as do many lizards. This suggests that damage from tail loss may be more severe than would typically be expected in a reptile employing such a strategy.

The frequency and potential costliness of tail damage in this species, compounded with its gregarious nature (Dundee and Miller 1968; Fitch 1975), suggest that kin selection might play a role in sustaining this behavior. A very small refuge can often house over half-dozen *D. punctatus* (Dundee and Miller 1968). When *D. punctatus* detects a predator, its initial response is to flee but when this option is not available, the snake performs the coil display (Davis 1948, Ernst and Barbour 1989). The order in which these tactics are employed suggests tail-coiling is used as a last resort and not as a preliminary strategy. If the animal is unable to escape, and it performs tail-coiling, it decoys the attack to a less vital part of the body. This allows for the possibility of escape during the struggle and decreases the likelihood of mortality. Escape does occur based upon the higher frequencies of tail damage we observed in *D. punctatus* versus the non-tail-coiling species. The bite of *D. punctatus* is fairly innocuous, but under rare circumstances could inflict damage on a predator holding its tail as well. While struggling with a tail-held prey, as opposed to one in

which the head were grasped, the predator may derive lost opportunity (Stephens and Krebs 1986) as the other potential prey escape. This interaction undoubtedly increases handling time, further increasing the cost of predation to the adversary (Schoener 1971). Tactics such as this may improve the likelihood the predator will give up, and escape will ensue. The increased handling in the aforementioned predation event might ensure neighboring, related snakes escape to safety. The victim, even if eaten, may maximize its inclusive fitness (Hamilton 1964, 1970) through its relatives' survival and later reproduction. It is important that future studies investigate the relatedness between individuals within *D. punctatus* aggregations to help further explain the nature of tail-coiling in this species.

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