Diet Specialization by the Scarlet Kingsnake, *Lampropeltis elapsoides* (Colubridae)

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Based on 34 natural prey items, *Lampropeltis elapsoides* eats primarily elongate squamates (97%), especially skinks (74%) and colubroid snakes (15%). No ontogenetic or geographic variation is evident; prey items are swallowed headfirst and average 19% of predator mass. The diet substantially overlaps that of juveniles of some other lampropeltines, including sympatric *L. triangulum*, but is unusually narrow compared to adults of most other species.

Scarlet Kingsnakes (*Lampropeltis elapsoides*), now recognized as distinct from the much more widespread Milksnake (*L. triangulum*), occur at low and moderate elevations from Virginia to Florida, thence west to Kentucky and Louisiana (Conant and Collins 1998). The two species are sympatric with little or no hybridization at several contact zones, the best studied of which are in western Kentucky and adjacent Tennessee (Armstrong et al. 2001) and North Carolina (Harper and Pfennig 2008). These secretive coral snake mimics (Greene and McDiarmid 2005, Harper and Pfennig 2008) range in total length (TL) from 130 mm at hatching to a maximum of 576 mm (Wright and Bishop 1915, Williams 1988), and, along with other lampropeltines, are of interest from diverse perspectives (e.g., Rodríguez-Robles and de Jésus Escobar 1999, Pyron and Burbrink 2009).

ALAN CRESSLER

Scarlet Kingsnakes (*Lampropeltis elapsoides*) occur at low and moderate elevations from Virginia to Florida and west to Kentucky and Louisiana. In contrast with published reports, these snakes are not dietary generalists.

SUZANNE L. COLLINS, CNAH

Red Milksnakes (*Lampropeltis triangulum syspila*) show a significant dietary shift with increasing size, shifting from reptiles to mammals as they get larger).

Herein, we: (i) Provide a first critical analysis of the feeding ecology of *L. elapsoides*; (ii) refute implications that it is a dietary generalist (e.g., "food includes small snakes and lizards, baby mice, small fish, insects, and earthworms"; Conant and Collins 1998:375); and (iii) assess its potential interactions with other sympatric snakes, especially Red Milksnakes (*L. t. syspila*) in the Kentucky-Tennessee contact zone. We are especially pleased that Henry Fitch provided unpublished data for this project and enjoyed reading our manuscript during the summer of his 100th year.

Materials and Methods

We examined stomach contents of preserved *L. elapsoides* (for methods see Greene and Rodríguez-Robles 2003) at Archbold Biological Station, Carnegie Museum of Natural History, and North Carolina State Museum of Natural Sciences, then integrated those data with EJZ.'s field observations from Kentucky; anecdotes provided by J.D. Groves (pers. comm.) and J.D. Wilson (Savanna River Ecology Lab files); and credible literature records (Carr 1940, based on Florida Museum of Natural History 1568; K.L. Krysko, pers. comm.; Mount 1963; Brown 1979; Palmer and Braswell 1995, excluding a Worm Snake, *Carphophis amoenus*, which field notes indicate was eaten after capture; Lee 2006). We omitted records cited by Williams (1988) that were based on captives or unsupported by explicit data (Brimley 1905, Ditmars 1907, Brode and Allison 1958); we excluded Wright and Bishop's (1915:167) report of "an angleworm and … two killifishes," because those prey are otherwise unknown in the diet of any lampropeltine (Rodríguez-Robles and de Jésus Escobar 1999) and more plausibly stomach contents from an ingested item (e.g., Eastern Gartersnake, *Thamnophis sirtalis*). We assessed dietary overlap with *L. t. syspila* based on five records from Kentucky and Tennessee obtained by EJZ and 22 records from Kansas (Fitch 1999, pers. comm.).

Results

Thirty-four prey items from 32 *L. elapsoides* (mean 1.1 items/snake) include 13 *Scincella lateralis* (Ground Skink, including 1 set of 5 eggs and 1 tail), 6 *Plestiodon inexpectatus* (Southeastern Five-lined Skink), 1 *P. egregius* (Mole Skink), 2 *Plestiodon* sp., 3 unidentified skinks, 1 set of 4 lizard eggs, 2 *Aspidoscelis sexlineata* (Six-lined Racerunner), 2 *Diadophis punctatus* (Ring-necked Snake), 1 *Tantilla coronata* (Southeastern Crowned Snake), 1 *Thamnophis* sp. (gartersnake), 1 *Virginia striatula* (Rough Earthsnake), and 1 nestling rodent. They encompass ≥9 prey species, including 33 (97%) somewhat to very elongate, mostly smooth-scaled squamate reptiles; 25 (74%) were skinks (mainly 2 species) and 5 (15%) were colubroid snakes. Only 2 ate multiple items, so we cannot evaluate whether individuals specialize on particular prey types.

LAURIE J. VITT (TOP)

Preying mainly on slender squamates, such as reclusive skinks and small snakes, the diet of Scarlet Kingsnakes appears to be constrained by a small gape. Southeastern Five-lined Skinks (*Plestiodon inexpectatus*; top) and Ground Skinks (*Scincella lateralis*; bottom) are prominently represented in stomach samples.

SUZANNE L. COLLINS, CNAH (FOR BOTH IMAGES)

Small snakes in the diet of Scarlet Kingsnakes include Ring-necked Snakes (*Diadophis punctatus*; top) and Rough Earthsnakes (*Virginia striatula*; bottom).

The 34 prey items are from Florida (8), Kentucky (7), Louisiana (1), Mississippi (2), North Carolina (12), and South Carolina (4), and lizards predominated throughout the range. Florida *L. elapsoides* ate 7 lizards and a mouse; North Carolina prey included 10 lizards and 2 snakes, and, although Kentucky snakes occupy distinctive habitat (Armstrong et al.

Table 1. Data for individual Scarlet Kingsnakes (*Lampropeltis elapsoides*) and their prey. MR = mass ratio.

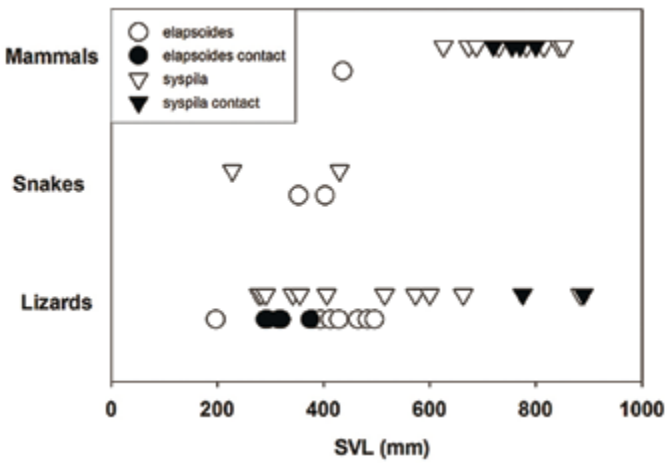
Locality	Size	Prey	MR	Direction	Date	Source
LA	353 mm, 9g	1 *Thamnophis* sp., 1 g	0.11	headfirst		CM 91903
FL	379 mm, 16 g	1 *Aspidoscelis sexlineata*, 6 g	0.38	headfirst		ABS
MI	403 mm, 18 g	*2 Diadophis punctatus*, 2 g, 3 g	0.11			Lee (2006)
			0.17			
FL	413 mm, NA	1 *Plestiodon inexpectatus*, NA				ABS
FL	429 mm, 13 g	1 skink, 2 g	0.15	headfirst	9/1936	CM 19840
FL	436 mm, 20 g	1 rodent, 4 g	0.20			ABS
GA		1 angleworm, 2 killifishes				CUMV 6242, W&B
FL	196 mm	1 *Scincella lateralis*			1/1937	Carr (1940) FMNH 1568
FL		1 *Scincella lateralis*				Carr (1940)
FL	~10 in	UID skink scales in feces				J.D.Groves (in litt.)
FL	300 mm	*Plestiodon egregius,* tail				Mount (1963)
SC		2 *Scincella lateralis*				Brown (1979)
SC		1 *Scincella lateralis*				Brown (1979)
SC	348 mm, 12.5 g	1 *Scincella lateralis*			4/17/07	J.D.Wilson (SREL)
NC, Moore	adult female	1 *Aspidocelis sexlineata*, juv.			9/1/2004	NCSM 04-2049
NC, Richmond	adult female	1 *Plestiodon inexpectatus*			4/13/2002	NCSM 02-364
NC, Craven	197 mm	1 *Scincella lateralis,* tail			9/12/1968	NCSM 33820
NC, Beaufort	483 mm	1 *Scincella lateralis* [5 eggs]			7/1/1968	NCSM/PB
NC, Craven	394 mm	1 *Plestiodon inexpectatus*			5/24/1968	NCSM 33819/PB
NC, Hyde	496 mm	1 *Plestiodon inexpectatus,* adult			4/30/1960	NCSM 972/PB
NC, Cateret	465 mm	1 *Plestiodon inexpectatus,* adult			4/25/1970	NCSM 9253/PB
NC, Bladen	294 mm	1 *Scincella lateralis,* adult				NCSM 15005/PB
NC, Brunswick		1 *Plestiodon inexpectatus*				P&B (1995)
NC, Brunswick		1 *Virginia striatula*				P&B (1995)
NC, Scotland		1 *Scincella lateralis*				P&B (1995)
NC, Scotland		1 *Tantilla coronata*				P&B (1995)
KY	370 mm	1 set of 4 reptile eggs (6–7 mm)			7/98	EMZ 1523
KY	375 mm	1 *Plestiodon* sp.		headfirst	6/98	EMZ 1525
KY	290 mm SV	1 *Scincella lateralis*, 4 cm SV		headfirst	7/98	EMZ 1527
	(est. 334 TL)					
KY	295 mm	1 *Plestiodon* sp., 4 cm SV			6/99	EMZ
KY	290 mm	1 skink			6/05	EMZ
KY	320 mm	1 *Scincella lateralis*			6/05	EMZ
KY	315 mm	1 *Scincella lateralis*, 4 cm SV			6/06	EMZ

2001), all of their prey were skinks. Snakes with prey were found in January (1), March (1), April (4), May (1), June (5), July (3), and September (3). They measured 196–496 mm in TL (mean 354 mm, n = 23), of which the two smallest ate *S. lateralis*, one of them (TL 197 mm) only a tail; the largest contained an adult *P. inexpectatus* and the only mammal was in a 436-mm adult. Prey/predator mass ratios were 0.11–0.38 (mean 0.19, n = 6), of which the largest was an *A. sexlineata* in a small adult snake (TL 379 mm), and all five items for which direction of ingestion was recorded were swallowed headfirst.

Scarlet Kingsnakes exhibit no ontogenetic change in diet; they thus completely overlap the diet of juvenile Red Milksnakes and partly that of adults. Eleven *L. t. syspila* within the size range of *L. elapsoides* (<576 mm TL) had eaten 8 skinks and 3 small snakes, whereas 17 larger adults (600–890 mm TL) had consumed 4 skinks (18%), a limbless lizard, and 17 mammals (77%) — a significant dietary shift with increasing size (reptiles versus mammals; Fisher's exact test, $p < 0.0001$).

Discussion

By preying mainly on slender squamates, *L. elapsoides* of all sizes resemble juveniles of *L. californiae* (K. Wiseman and H.W. Greene, unpubl. data), *L. triangulum* (Fitch 1999; M.F. Benard and H.W. Greene, unpubl. data), and *L. zonata* (Greene and Rodriguez-Robles 2003), as well as adults of



Prey types in relation to predator size for Scarlet Kingsnakes (*Lampropeltis elapsoides*) and Red Milksnakes (*L. triangulum syspila*), based on samples from a sympatric contact zone and elsewhere in the range of each species.

Table 2. Data for individual Red Milksnakes (*Lampropeltis triangulum syspila*) and prey.

Locality	Size	Prey	Direction	Date	Source
TN, Montgomery	720 mm	mammal hair		6/97	EMZ
KY, Lyon	755 mm	1 *Peromyscus* sp.		6/97	EMZ
KY, Trigg	770 mm	mammal hair		6/97	EMZ
KY, Marshall	775 mm	1 *Plestiodon* sp. 80 mm	headfirst	6/00	EMZ
TN, Lake	890 mm	1 *Plestiodon* sp. 70 mm		10/03	EMZ
TN, Lake	800 mm	1*Peromyscus* sp., young with hair		5/06	EMZ
KS	228 mm	1*Diadophis punctatus*		6/18/66	HSF
KS	278 mm	1*Plestiodon fasciatus*, 1st yr		4/86	HSF
KS	283 mm	1 *Plestiodon obsoletus*, tail only		9/21/66	HSF
KS	291 mm	1 *Plestiodon fasciatus*, juv.		4/30/66	HSF
KS	342 mm	1 *Plestiodon fasciatus*, adult		9/25/64	HSF
KS	355 mm	1 *Plestiodon fasciatus*, juv.		9/17/73	HSF
KS	406 mm	1 *Plestiodon fasciatus*, gravid ad.		6/14/66	HSF
KS	430 mm	1 *Carphophis amoenus*, adult		5/26/55	HSF
KS	430 mm	1 set 3 *Diadophis punctatus* eggs		7/16/78	HSF
KS	515 mm	1 *Plestiodon fasciatus*, ad. & 5 eggs		6/26/78	HSF
KS	573 mm	1 *Plestiodon fasciatus*, adult		5/22/66	HSF
KS	600 mm	1 *Plestiodon fasciatus*, 1st yr		5/18/60	HSF
KS	626 mm	2 *Microtus ochrogaster*, juveniles		6/7/93	HSF
KS	663 mm	1 *Plestiodon fasciatus*, adult		5/7/67	HSF
KS	673 mm, 90 g	4 *Microtus ochrogaster*, juv. @15 g		10/8/86	HSF
KS	688 mm	1 *Blarina hylophaga*		5/23/93	HSF
KS	730 mm	1 *Blarina hylophaga*		4/17/81	HSF
KS	782 mm	1 *Cryptotis parva*		10/10/90	HSF
KS	815 mm	1 *Microtus* sp.		8/18/67	HSF
KS	845 mm	2 *Microtus ochrogaster*, nestlings		7/23/92	HSF
KS	852 mm	1 *Microtus ochrogaster*, adult		5/26/90	HSF
KS	884 mm	1 *Ophisaurus attenuatus*, adult		8/1/61	HSF

some other small colubroid snakes (e.g., *Hypsiglena*, Rodríguez-Robles et al. 1999). Compared to other *Lampropeltis*, Scarlet Kingsnakes have pointed snouts and fused head scales suggestive of fossorial habits (Wright and Bishop 1915, Williams 1988), and they are typically found under cover objects, especially bark on old fallen logs and vertical stumps (Palmer and Braswell 1995, Reichling 2008). Accordingly, this species might simply be a habitat specialist, its narrow diet constrained by small gape and high encounter rates for reclusive skink and snake prey.

Additional lines of evidence imply Scarlet Kingsnakes are specialized predators (for general discussions see Rodríguez-Robles and Greene 1999, Brischoux et al. 2009). With 82% of its diet lizards and 89% of those items skinks, *L. elapsoides* has a narrower diet than another lampropeltine, *Rhinocheilus lecontei* (Long-nosed Snake), with a diet consisting of 65% lizards and 72% (48% of total items) teiids (*Aspidoscelis*); respective means for 55 other snake species in which lizards are modal prey are 75% and 47% (Rodríguez-Robles and Greene 1999). Moreover, *L. elapsoides* has the highest incidence of skinks in the adult diet of any North American serpent (Ernst and Ernst 2003) and its anterior teeth are enlarged like those of other skink specialists (Greene 1989). Finally, throughout its range, *L. elapsoides* co-occurs with *S. lateralis* and two to four species of *Plestiodon*, whereas, elsewhere in North America, no more than two species of skinks are typically sympatric (maps in Conant and Collins 1998, Jones and Lovich 2009).

In terms of prey taken by other sympatric snakes, *L. elapsoides* partly overlaps *Coluber constrictor* (Racer), *L. getula* (Common Kingsnake), *L. extenuata* (Short-tailed Snake), and *Micrurus fulvius* (Eastern Coralsnake), of which the first two have much broader diets and the others are moderately to exclusively specialized on snakes (Ernst and Ernst 2003). As MacArthur (1972) pointed out, one way to trump potential competitors is to eat them, and *M. fulvius* indeed preys on both *P. inexpectatus* (ABS field notes) and *L. elapsoides* (Krysko and Arbdelfattah 2002). None of those other snakes specializes on skinks, but we have demonstrated that juveniles of *L. t. syspila* do so, and adults of that species partially overlap the diet of sympatric *L. elapsoides*. Additional studies of Scarlet Kingsnakes in a community ecological context will likely provide further insights into specialization, speciation, mimicry, and other evolutionary processes.

Acknowledgments

We thank K.L. Krysko, J.N. Layne, and S.P. Rogers for access to and/or information on preserved specimens; H.S. Fitch, J.D. Groves, and J.D. Wilson for use of their observations; and J.D. Groves and L.J. Vitt for insightful feedback.

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A Survey of Gravid Snakes at Several Sites in Southern Wisconsin

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Photographs by the author except where indicated.

Fitch (1987a) indicated that morphological measurements, particularly measures of snout-to-vent length (SVL), provide some of the most useful information that can be obtained from field-based research on snakes. Unfortunately, published research that focuses on natural history, which includes morphological data such as snake size, has declined sharply in recent years (Henderson and Powell 2009, McCallum and McCallum 2006). In some cases, natural history observations considered "anecdotal" are even treated with scorn by researchers. As Fitch (1987b) suggested, such reactions to life history studies are unfortunate, and information that may be considered anecdotal still has a valuable role in increasing the understanding of many species' ecological needs. Therefore, this information should be published.

Considerable data have been published on the ecology and life history of several natricine snake species, particularly the Common Garter Snakes (*Thamnophis sirtalis*; e.g., Fitch 1965, 1999, 2001). These include information on aspects of their morphology, such as size (SVL) and weight. However, certain small fossorial species, such as members of the genus *Storeria* have received less attention. In addition, although the size of "mature" females has been reported for several species at some locations in the upper midwestern United States (e.g., Ohio and Michigan), such information is rare from populations in Wisconsin. Furthermore, few if any data from Wisconsin have been published, with the possible exception of technical reports that are not easily obtained. Such information is valuable for determining numerous aspects of the biology of these species, such as size at sexual maturity and morphological characteristics of regional

An example of typical Eastern Garter Snake (*Thamnophis sirtalis sirtalis*) habitat in Wisconsin.