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ARTICLES

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A New Report of Albinism in the Common Garter Snake (*Thamnophis sirtalis*), and a Review of Existing Records: Is There a Geographic Bias in Observations?

Albinism is one of the most striking aberrations of body color in vertebrates, arising from an absence of melanin in the integument (McCardle 2012). Errors at any of several steps in the pathway of melanogenesis can block the production of melanin in the skin, largely (but not exclusively) as a result of autosomal recessive mutations (Bechtel 1995). In mammals, oculocutaneous albinism is associated with the expression of white skin and pale yellow hair due to a lack of accessory pigments in these structures (Bechtel 1995; Carden et al. 1998). In contrast, squamate reptiles normally possess additional classes of long-wavelength pigment in the integument expressed independently of melanin: pteridines, which are naturally produced in the dermis, and carotenoids, which must be acquired in the diet but may be secondarily stored in the dermis (Bechtel 1995). As a consequence, albino squamates that retain these accessory pigments typically exhibit yellow or red skin (xanthic albinism; “albino” sensu Bechtel 1995). The complete lack of endogenous integumentary pigment in squamates (i.e., no melanin or pteridine) is termed leucism, and the skin of leucistic reptiles is white (Bechtel 1995). Leucistic reptiles are also often referred to as albinos, especially in the older literature (McCardle 2012). However, xanthic albinos and axanthic albinos (i.e., leucistics) are phenotypically distinct, and the latter are especially uncommon (Bechtel 1991).

Reports of albinism in reptiles have been published on an occasional basis throughout the last century (e.g., Hensley 1959; Dyrkacz 1981 and references therein), but multiple records for an individual species remain the exception rather than the rule (Bechtel and Bechtel 1981; Krecsák 2008). The major reason is that albinos are rare: perhaps as few as 1 in 30,000 individuals in wild populations of a given species may exhibit the condition (Bechtel 1995). With the possible exception of species that inhabit aphotic environments (Gross et al. 2009; McCardle 2012), albinos are thought to experience reduced fitness relative to non-albino conspecifics, ensuring that the frequency of albinos remains low (Bechtel 1995; Krecsák 2008). At least partly as a consequence,

reports of albinism are scarce for most individual species, limiting the potential to test hypotheses for the biological significance of albinism, and integumentary coloration more generally.

One exception to this generalization is the Common European Adder (*Vipera berus*). Krecsák (2008) found evidence that albinism in this widely distributed species was more common in the northern part of its range (i.e., Scandinavia) than in the south (central and southern Europe). Several possible explanations were invoked to explain this pattern: high local densities might provide protection to albinos by dilution effect; the reduced species diversity and population sizes of mammalian and avian snake predators at northern latitudes further reduce predation pressure on albinos; and offshore islands, the source of several specimens, may be linked to increased rates of albinism due to genetic drift mechanisms, inbreeding, or both (Krecsák 2008).

Another possible explanation is that populations at northern latitudes may be less vulnerable to negative effects of UV radiation, diminished at northern latitudes relative to the tropics. This hypothesis has been invoked to explain the reduction of integumentary melanin in human populations at northern latitudes as compared with those found near the equator (Jablonski and Chaplin 2010), but conceivably could help explain elevated frequencies of albinism at high latitudes in some other vertebrate groups. We note that some ectothermic organisms exhibit *increased* melanism in populations at higher latitudes, apparently as an adaptation for increased thermoregulatory efficiency (e.g., Clusella Trullas et al. 2007). This overall pattern, however, is not incompatible with relaxed selection on albinos via reduction in UV-induced skin damage.

The Common Garter Snake (*Thamnophis sirtalis*) is one of the most wide ranging reptiles in North America, found from Florida and southern Quebec in the east, to California and British Columbia in the west (Rossman et al. 1996). Isolated populations are known as far south as northern Mexico, and as far north as the Northwest Territories of Canada. The latter populations represent the most northerly known for any snake in the Western Hemisphere (Rossman et al. 1996). Twelve subspecies are presently recognized in this taxon, of which the most widely distributed is the Eastern Garter Snake, *T. s. sirtalis* (Rossman et al. 1996).

In April 2013, a female albino Eastern Garter Snake *T. s. sirtalis* was discovered by one of us (KMD) in a residential neighborhood in Macon, Georgia, USA. Following this discovery, we reviewed existing reports of albinism in natural populations of *T. sirtalis*

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PHOTO BY K. M. DRACE

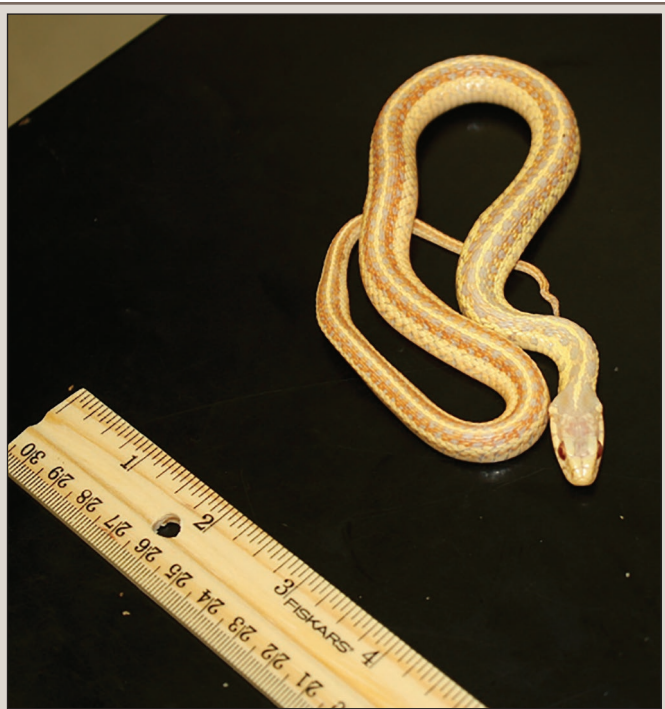


FIG. 1. Subadult albino female Eastern Garter Snake (*Thamnophis s. sirtalis*) from Macon, Georgia.

and other species of *Thamnophis* (Hensley 1959; Gilboa and Dowling 1974; Dyrkacz 1981). In light of Krecsák's (2008) study, and the exceptionally broad latitudinal distribution of *T. sirtalis*, we asked whether albinism in *T. sirtalis* also varies along a latitudinal gradient. We also considered whether observations of aberrant snakes vary along a longitudinal gradient. Given the diversity of eastern and western habitats utilized by this species in North America (e.g., subtropical marshland, montane forest, prairie, oak savannah; see Rossman et al. 1996) and the variable thermal, lighting, and predator-prey regimes experienced across these populations, it is conceivable that selection against albinos might be variable along an east-west gradient, independent of any possible north-south cline.

In this report, we first provide details on the newly discovered albino specimen of *T. s. sirtalis*. We then review existing published reports and museum specimens of albinos and leucistic *T. sirtalis* and other species of *Thamnophis*, and conduct statistical tests of the hypothesis that albinism and leucism vary geographically in *T. s. sirtalis*. We also provide perspective on the opportunities and challenges that await researchers interested in testing hypotheses for the functional significance of albinism in *T. sirtalis* and other reptiles.

MATERIALS AND METHODS

On 27 April 2013, KMD captured a female albino *T. s. sirtalis* (Fig. 1) in the backyard of his residence in Macon, Bibb Co., Georgia (32.85°N, 83.66°E) around 1200 h. This urban environment is an older, well-established neighborhood where most of the houses were built before 1915. The weather was mostly sunny with a temperature of about 20°C; however, the immediate surroundings where the specimen was found remain shady and moist most of the time (KMD, pers. obs.). The snake was discovered when, upon approach, it quickly retreated to a narrow space between a loose pile of red bricks and the wood

paneling of the side of the house where it was collected. The appearance of this specimen coincided with other observations of snakes in the immediate area, probably a function of the onset of the spring breeding season in this species (Reed and Gibbons 2008). After capture, the snake was placed in a dark, cool environment until morphometric data could be collected two days later.

We then conducted a review of existing records of albinism and leucism in both *T. sirtalis* (Table 1) and other *Thamnophis* species (Table 2), limiting our search to records described in published reports, as well as searches of museum specimen databases provided in HerpNet2 (www.herpNet2.org). We list only those reports where at least state- or province-level locality data was provided; when subspecies was not given, we tentatively assigned putative subspecies using range maps in Rossman et al. (1996). We did not personally examine any preserved material; in many cases, final disposition of the described specimen(s) was not indicated in the original report. In this report, we use the definitions of Bechtel (1995) and restrict the terms "albino" to amelanistic xanthic specimens, and "leucistic" to amelanistic axanthic specimens. We note that the term "albino" has been applied by various authors to include a wider or narrower range of aberrant phenotypes (e.g., Harris 1970). Thus, it is conceivable that some listed specimens might not represent albinism as defined here (*sensu* Bechtel 1995).

To test whether the distribution of albino *T. sirtalis* differed from those of non-mutant (putative wild-type) *T. sirtalis*, we also searched HerpNet2 for all records of *T. sirtalis* specifically, including those listed under older genera (*Eutaenia* and *Natrix*). Of a total of 25979 records of this species, 9823 included latitude and longitude data, and were thus available for use in analysis. As HerpNet2 provides fields for entry of significant notes regarding specimens (such as the occurrence of albinism), we assumed that albinism would ordinarily be noted if it was present. Promisingly, we found one record (MSUM 183) in HerpNet2 described as albino that confirmed a literature report (Hensley 1959). However, we also found three records of albinism in the literature that were not described as such in their HerpNet2 specimen records (AMNH 162456, Hensley 1959; CM 48368, Dyrkacz 1981; CM 26259, Barton 1947). Thus, it is likely that some other specimens given in HerpNet2, but lacking supporting literature documentation, and which we assumed were wild-type in our analysis are in fact albino or leucistic. Prior to analysis, two of three records of albinos found in the literature but not described as such in HerpNet2 were removed to prevent their duplicative use in analysis; the third such record did not contain latitude and longitude data in HerpNet2 and therefore was not listed twice in the analyzed data set. One additional record of a putative wild-type *T. sirtalis* had clearly questionable locality data associated with it, and was also removed. We used nonparametric tests, as data for wild-type and albino *T. sirtalis* did not meet conditions for normality. All statistical analyses were conducted using Systat 12 (Systat Software, Inc. 2007).

RESULTS

Albino T. s. sirtalis from Macon, Georgia.—Measurements of this specimen were obtained on 29 April, two days after collection. At that time its body mass was 25.5 g, and its total length was 410 mm. Consistent with earlier reports of albino (*sensu* Bechtel 1995) *T. s. sirtalis*, this specimen exhibits a generalized yellow ground color with orange-red and blue-

TABLE 1. Reports of Common Garter Snakes (*Thamnophis sirtalis*) exhibiting albinism or leucism obtained through literature and museum database searches. Only records where state- (U.S.) or province-level (Canada) locality information was available are listed. An asterisk (*) indicates records where no subspecies assignment was given in the original publication or online museum database record, and is inferred from the geographic range of subspecies of *T. sirtalis* given in Rossman et al. (1996). Morph is indicated only when the source description(s) of the specimen provides sufficient information to suggest either albinism or leucism specifically. Multiple specimens from the same observation are indicated in parentheses under Age Class.

Lat. (N)	Long. (E)	Subspecies	State/ Province	County/ Division/ Reg. County Municipality/ Reg. District	Locality	Year	Month	Morph	Age Class	Total Length	Sex	Last Known Disposition	Specimen ID
32.8	-83.7	<i>sirtalis</i>	GA ¹	Bibb	Macon	2013	Apr	Albino	Subadult	420 mm	F	Mercer University	N/A
33.7	-84.2	<i>sirtalis</i>	GA ²	Dekalb	Shoal Creek	1974	July	Albino	Subadult	305 mm	—	Fernbank Science Ctr	—
33.8	-84.2	<i>sirtalis</i>	GA ²	Dekalb	—	1976	Aug	Albino	Subadult	457 mm	—	Fernbank Science Ctr	—
34.4	-81.1	<i>sirtalis</i> *	SC ³	Fairfield	—	1991	Sept	Albino	Adult	660 mm	F	Riverbanks Zoological Park	—
34.8	-85.0	<i>sirtalis</i>	GA ²	Whitfield	Dalton	1985	Apr	Albino	Subadult	430 mm	F	Atlanta Zoo	—
38.2	-81.5	<i>sirtalis</i> *	WV ⁴	Kanawha	Cabin Creek	1975	Oct	—	Subadult	—	—	Unknown	—
38.7	-93.2	parietalis	MO ⁵	Pettis	Sedalia	1960	Oct	Albino	Adult	673 mm	—	S.L. Kramer	—
38.7	-93.2	parietalis*	MO ⁴	Pettis	Sedalia	1965	—	—	Adult	—	—	Unknown	—
38.7	-77.8	<i>sirtalis</i>	VA ⁶	Fauquier	Warrenton	1992	July	Leucistic	Adult	600 mm	F	S.H. Shively and J. C. Mitchell	—
39.1	-84.5	<i>sirtalis</i> *	OH ⁴	—	Cincinnati	1975	June	—	—	—	—	Cincinnati Zoo	—
39.2	-84.5	<i>sirtalis</i> *	OH ⁴	Hamilton	Cincinnati	1948	Oct	—	Adult	—	—	Cincinnati Museum of Natural History	CMNH 2659
39.3	-76.6	<i>sirtalis</i>	MD ⁷	—	Westport	1961	Sept	—	—	—	—	H.S. Harris, Jr.	RS333HSH
39.7	-78.9	<i>sirtalis</i>	MD ⁸	Allegany	Frostburg	1962	May	—	Adult	508 mm	F	R. Franz	—
40.0	-83.0	<i>sirtalis</i> *	OH ⁹	Franklin	Columbus	1956	—	—	—	—	—	Columbus Zoo	—
40.2	-75.5	<i>sirtalis</i> *	PA ⁴	Montgomery	Trappe	1966	—	Leucistic	—	—	—	Unknown	—
40.3	-86.1	<i>sirtalis</i>	IN ⁹	Tipton	—	1954	Aug	—	—	—	—	American Museum of Natural History	R-162456 (=AMNH 162456)
40.3	-78.9	<i>sirtalis</i>	PA ⁴	Cambria	Johnstown	1968	Sept	Albino	Subadult	—	—	Carnegie Museum of Natural History	CM 48368

TABLE 1. Continued.

Lat. (N)	Long. (E)	Subspecies	State/ Province	County/ Division/ Reg. County Municipality/ Reg. District	Locality	Year	Month	Morph	Age Class	Total Length	Sex	Last Known Disposition	Specimen ID
40.5	-80.0	<i>sirtalis</i>	PA ¹⁰	Allegheny	Pittsburgh	1941	—	Albino	Adult	551 mm	F	Carnegie Museum of Natural History	CM 26259
41.0	-76.6	<i>sirtalis</i>	PA ¹¹	Montour	Danville	1974	Nov	Albino	Subadult	406 mm	F	Philadelphia Zoological Gardens	—
41.3	-72.9	<i>sirtalis</i> *	CT ⁹	New Haven	New Haven	1956	—	—	—	—	—	Not collected	N/A
41.4	-85.4	<i>sirtalis</i> *	IN ⁴	Noble	Albion	1974	—	—	—	—	—	Unknown	—
41.7	-83.6	<i>sirtalis</i> *	OH ⁴	—	Toledo	1972	May	—	Neonate (3)	—	—	Unknown	—
41.7	-83.6	<i>sirtalis</i> *	OH ¹²	Lucas	Toledo	1988	July	Albino	Subadult	220 mm	M	Riverbanks Zoological Park	—
41.7	-83.6	<i>sirtalis</i> *	OH ¹²	Lucas	Toledo	1992	July	—	Neonate (7)	—	—	Unknown	—
41.7	-83.6	<i>sirtalis</i> *	OH ¹²	Lucas	Toledo	1993	June	—	Adult	590 mm	M	Unknown	—
41.7	-85.3	<i>sirtalis</i> *	IN ⁴	LaGrange	Mongo	1974	—	—	—	—	—	Unknown	—
42.1	-78.7	<i>sirtalis</i>	NY ¹³	Cattaraugus	Allegheny State Park	1944	Aug	Albino	—	—	—	Allegheny State Park Zoo	—
42.4	-78.3	<i>sirtalis</i> *	NY ⁹	Allegheny	Rushford	1947	Nov	—	—	—	—	Buffalo Society of Natural Sciences	BSNS (uncat.)
42.5	-73.2	<i>sirtalis</i>	MA ¹⁴	Berkshire	Pittsfield	1979	Aug	Albino	Neonate	190 mm	—	R.D. Bartlett	—
42.9	-79.0	<i>sirtalis</i>	ON ¹⁵	Niagara	Fort Erie	—	—	—	—	—	—	Buffalo Zoo	None
43.0	-88.0	<i>sirtalis</i>	WI ¹⁶	Milwaukee	—	—	—	—	—	—	—	Milwaukee Public Museum	MPM 2600
43.3	-75.2	<i>sirtalis</i>	NY ¹⁷	Oneida	Barneveld	1959	Sept	Leucistic	Adult	559 mm	M	S. Christman	—
43.4	-83.9	<i>sirtalis</i> *	MI ⁹	Saginaw	Bridgeport	1956	Oct	Albino	—	—	—	Michigan State University Museum (= MSUM HE.183)	MSUM 183
44.5	-77.5	<i>sirtalis</i>	ON ¹⁵	Hastings	Moir Lake	1970	—	Albino	Adult	—	—	Not collected	N/A
44.5	-77.5	<i>sirtalis</i>	ON ¹⁵	Hastings	Moir Lake	1970	Aug	Albino	Neonate (2)	—	—	Not preserved	N/A
45.4	-75.7	<i>sirtalis</i>	ON ¹⁸	Ottawa	Ottawa	1986	Sept	Albino	Subadult	210 mm	—	National Museum of Natural Sciences	NMNS 28723
45.4	-75.7	<i>sirtalis</i>	ON ¹⁹	Ottawa	Ottawa	1988	Aug	Albino	Subadult	205 mm	—	National Museum of Natural Sciences	NMNS 31336
45.4	-75.7	<i>sirtalis</i>	ON ¹⁹	Ottawa	Ottawa	1988	Sept	Albino	Subadult	250 mm	—	National Museum of Natural Sciences	NMNS 31535

(continued on next page)

TABLE 1. Continued.

Lat. (N)	Long. (E)	Subspecies	State/ Province	County/ Division/ Reg. County Municipality/ Reg. District	Locality	Year	Month	Morph	Age Class	Total Length	Sex	Last Known Disposition	Specimen ID
45.7	-75.8	<i>sirtalis</i>	QC ¹⁹	Les-Collines- de-l'Outaouais	Val-des-Monts	1988	Mar	Albino	—	—	—	Released at capture site	N/A
48.4	-123.4	<i>pickeringii</i> *	BC ⁹	Capital	Victoria	1956	Aug	—	—	—	—	Royal British Columbia Museum	PMC 910
48.8	-122.5	<i>pickeringii</i> *	WA ⁴	Whatcom	Bellingham	1972	Aug	—	Neonate	—	—	Washington Public Zoo	—
—	—	<i>sirtalis</i> *	NY ⁹	—	—	—	—	—	—	—	—	Bronx Zoo	—
—	—	—	ON ⁹	—	—	—	—	—	—	—	—	Royal Ontario Museum	—
¹ This report			⁵ Kramer 1960		⁹ Hensley 1959			¹³ Eaton, Jr. 1945		¹⁷ Anonymous 1960			
² Cook 1986			⁶ Shively and Mitchell 1994		¹⁰ Barton 1947			¹⁴ Bartlett 1981		¹⁸ Coad and Coad 1987			
³ Smith and Schuett 1992			⁷ Harris 1970		¹¹ Groves 1976			¹⁵ Weller 1983		¹⁹ Coad et al. 1989			
⁴ Dyrkacz 1981			⁸ Franz 1968		¹² Smith 1997			¹⁶ Dickinson 1950					

lavender color elements arranged in stripes; thus, the overall body color pattern is retained despite the absence of melanin. Scale rows 1–3 are uniform light yellow. Rows 4–8 are orange, with pale blue or lavender rectangular spots on rows 4 and 8 arranged in an alternating checkerboard pattern. A central yellow stripe occupies scale row 9. The ventral scales are a light yellow cream color. The distal portion of the tail exhibits a pronounced sinusoidal kink, suggesting a previous injury.

Albinism and leucism in T. sirtalis.—Including the specimen described here, we found 43 independent observations describing 52 cases of putative albinism or leucism in *T. sirtalis* (Table 1). Three observations described the birth of multiple albino offspring (Dyrkacz 1981; Weller 1983). Most of the original literature reports describing cases of albinism in *T. sirtalis* do not clarify whether a given specimen was specifically albino or leucistic (sensu Bechtel 1995). In 19 of these 43 cases, this distinction was clearly made in the original report, or could reasonably be inferred based on details of description of the specimen (see Table 1). Of these, only 3/19 individuals (16%) were reported to be leucistic, consistent with expectations that this phenotype is much rarer than albinism (sensu Bechtel 1995).

Of these 43 separate observations of aberrant Common Garter Snakes, at least 37 (88%) are definitely or probably the nominate subspecies *T. s. sirtalis*. Either albinism or leucism was reported in only 3 of 11 described subspecies (*sirtalis*, *parietalis*, and *pickeringii*) recognized by Rossman et al. (1996). Two of these (*sirtalis* and *parietalis*) represent the forms with the widest geographic range of any subspecies of Common Garter Snake, and their disproportionate representation among observations of albinism is therefore not unexpected.

Albinism and leucism in other Thamnophis.—We also examined reports of albinism in other species of garter snakes. Overall, we found 16 independent observations representing at least six species of *Thamnophis* exclusive of *T. sirtalis* (Table 2). In 13/16 records, albinism or leucism was specifically noted, and/or a distinction could be made based on a description of the reported specimen(s). Of these 13 specimens, only 1 (8%) was leucistic, again reinforcing the expectation that leucism (sensu Bechtel 1995) is a much rarer phenomenon than albinism in garter snakes more generally.

Geographical variation in albinism.—Inspection of Table 1 suggests that more putative albinos and leucistics have been found in areas towards the northern part of its range. Figure 2A graphically represents this trend, revealing a peak in the number of independent observations around 40°N latitude. However, we found no difference in the latitude of records of albino/leucistic snakes as compared with records of putative wild-type snakes (Mann-Whitney $U = 203269$; $P = 0.91$; albinos/leucistics: $\bar{X} = 41.0^\circ\text{N}$, wild-type: $\bar{X} = 41.2^\circ\text{N}$). The latitudinal distribution of putative wild-type snakes from the HerpNet2 database (data not shown) exhibits the same general pattern as that observed for albinos/leucistics, supporting the notion that the peak observed in Fig. 2A reflects biased sampling of *T. sirtalis* more generally.

The longitudinal distribution (Fig. 2B) reveals a central peak around -80°E longitude (i.e., from South Carolina to Ontario), though the paucity of records from much of the central and western part of the range of *T. sirtalis* may be problematic (Rossman et al. 1996). Nevertheless, there was a difference in the longitude associated with records of albinos/leucistics as compared with putative wild-type snakes (Mann-Whitney $U = 271642$; $P = 0.0001$); specifically, aberrant snakes were more

TABLE 2. Reports of albinism or leucism in species of *Thamnophis* exclusive of *T. sirtalis* obtained through literature and museum database searches. Only records where state- (U.S.), province- (Canada), or district-level (Belize) locality information was available are listed. An asterisk (*) indicates records where no species assignment was given in the original source. Morph is indicated only when the source description(s) of the specimen provides sufficient information to suggest either albinism or leucism specifically. Multiple specimens from the same observation are indicated in parentheses under Age Class.

Lat. (°N)	Long. (°E)	Species	Subspecies	State/Province	County/District	Locality	Year	Month	Morph	Age Class	Total Length	Sex	Last Known Disposition	Specimen ID
17.5	-88.3	<i>marcianus</i>	<i>praeocularis</i>	—	Belize	British Army Airport Camp	1968	—	Leucistic	—	—	—	Milwaukee Public Museum	MPM 7759
31.5	-97.1	<i>proximus</i>	—	TX ¹	McLennon	Waco	1958	Aug	Albino	Adult	420 mm	—	University of Michigan Museum of Zoology	—
37.3	-107.9	<i>elegans</i>	<i>vagrans</i>	CO ²	La Plata	Durango	1975	May	Albino	Subadult	276 mm	F	University of Colorado Museum of Natural History	UCM 52728
37.7	-106.6	<i>elegans</i>	<i>vagrans</i>	CO ³	Rio Grande	South Fork	—	—	—	Subadult	221 mm	F	—	—
39.2	-108.1	<i>elegans</i>	<i>vagrans*</i>	CO ⁴	Grand Junction	Mesa	1960	Aug	—	—	—	—	University of Colorado Museum of Natural History	UCM 15296
40.0	-105.4	<i>elegans</i>	<i>vagrans</i>	CO	Boulder	Sugarloaf Mountain	1954	June	Albino	—	—	—	University of Colorado Museum of Natural History	UCM 7068
41.6	-88.4	<i>radix</i>	—	IL ⁴	Kendall	Yorkville	1975	Oct	—	Subadult	—	—	Brookfield Zoo	—
41.9	-87.6	<i>radix</i>	—	IL ⁵	Cook	Chicago	1950	Sept	Albino	Neonate	151 mm	—	University of Illinois Museum of Natural History	UIMNH 33858
41.9	-87.6	<i>radix</i>	—	IL ⁶	Cook	Chicago	1973	Sept	Albino	Neonate	235 mm	F	S. Dyrkacz	SD 058
42.3	-83.1	<i>butleri</i>	—	ON ⁷	Essex	Windsor	1985	—	Albino	—	—	—	P. Pratt	—
42.4	-114.5	<i>elegans</i>	<i>vagrans</i>	ID ⁸	Twin Falls	—	1961	Aug	Albino	Subadult	592 mm	F	Monte L. Bean Life Science Museum, Brigham Young University	BYUH 23690
42.6	-88.1	unknown	—	WI	Kenosha	Paddock Lake	1987	Aug	Albino	—	—	—	Milwaukee Public Museum	MPM 95; MPM 96
44.6	-123.9	<i>ordinoides</i>	—	OR	Lincoln	Toledo	1966	Sept	Albino	—	—	—	California Academy of Sciences	CAS 121124
46.5	-121.8	<i>elegans</i>	<i>vagrans</i>	WA ⁹	Lewis	Bishop	1934	June	Albino	—	—	—	Charles R. Conner Museum, Washington State University	—
47.0	-122.7	<i>ordinoides</i>	—	WA ¹⁰	Thurston	—	—	—	Albino	—	—	—	—	—
47.2	-122.3	<i>ordinoides</i>	—	WA ¹¹	Pierce	Puyallup	1972	Apr	Albino	—	495 mm	M	James R. Slater Natural History Museum, University of Puget Sound	PSM 10200

¹Rose 1959²Smith et al. 1975³Banta and Hahn 1966⁴Dyrkacz 1981⁵May 1952⁶Dyrkacz 1975⁷COSEWIC 2010⁸Tanner 1966⁹Svihla 1936¹⁰Brown et al. 1995¹¹Norman 1997

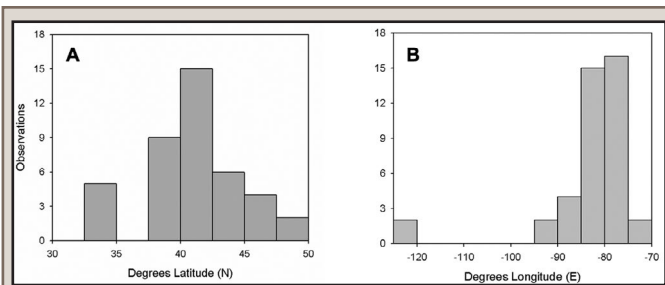


FIG. 2. Frequency histograms of unique observations of albinism and leucism in Common Garter Snakes (*Thamnophis sirtalis*) per degrees North latitude (A) and degrees East longitude (B). The latitude and longitude of each observation site were inferred from details of known site locality in the original source publication or museum description, and assessed using Google Earth. Where only county-level information was provided in the original description, we estimated the site latitude as an arithmetic mean of the most northerly and southerly latitudes associated with the geographical boundaries of each county. Two observations where at least county-level locality data were unavailable were excluded.

commonly reported from the eastern US (albinos/leucistics: \bar{X} = -83.1°E), whereas the mean longitude of records of wild-type specimens was shifted further west (wild-type: \bar{X} = -97.9°E).

We did not perform statistical analysis on the smaller data set of aberrant garter snakes of *Thamnophis* species exclusive of *T. sirtalis* (Table 2); however, we note that a majority of observations were also found at sites around 40°N latitude.

DISCUSSION

Albino T. s. sirtalis from Macon, Georgia.—According to Carpenter (1952), sexual maturity in *T. s. sirtalis* may be attained at a snout-vent length (SVL) around 400 mm. Although we did not measure SVL at the time of capture, populations of *T. s. sirtalis* in Michigan have tails that comprise about 25% of the total length. Assuming that Georgia populations of *T. s. sirtalis* have similar growth patterns, by extrapolating an SVL of ~ 300 mm at the time of collection we interpret that the individual was a subadult when captured, probably born the previous spring or summer (Carpenter 1952). We acknowledge, however, that geographic variation in life history traits in *T. sirtalis* is extensive (Rossman et al. 1996), and growth rates in populations from Georgia might differ from those in Michigan. Interestingly, a snake strongly resembling the specimen described here was seen about two weeks prior to this observation in the same area of the Drace residence (KMD, pers. obs.), suggesting that the same snake may have been resident in the area for at least a few weeks. Although the possibility that it was a separate specimen should not be discounted (e.g., Dyrkacz 1981), we know of no other reports of putative albino snakes from the area.

Albinism in subspecies of T. sirtalis.—Although *T. sirtalis* contains at least 11 described subspecies, albinism has been only reported in just three subspecies, two of which (*sirtalis* and *parietalis*) have the largest geographic ranges of the species. Is albinism less common in subspecies of *T. sirtalis* where it has not yet been reported? Several lines of evidence suggest that this is probably not the case. First, many subspecies of *T. sirtalis* for which albinism has not been recorded have small geographic ranges (Rossman et al. 1996), and several occur in relatively remote areas of western North America. Thus, albinism may be less likely to be encountered in some of these populations,

simply because of difficulties in accessing appropriate habitat. In addition, population bottlenecks and associated inbreeding can generate an increase in homozygous recessive traits such as albinism (e.g., Gilhen et al. 2012). As a consequence, some isolated populations of *T. sirtalis* may be subject to higher rates of albinism than those seen elsewhere. Finally, it is also likely, in our view, that some relatively recent observations of albinism in this species have not been published, perhaps due in part to a lack of perceived scientific interest in additional observations. Although this is conjectural, we note that the most recent published report we found for albinism in any population of Common Garter Snake was that of Smith (1997).

Geographical variation in albinism.—We considered whether records of albinism and leucism in *T. sirtalis* indicated a geographic bias to the distribution of albinos and leucistics in this species, as has been described in *V. berus* (Krečsák 2008). A strong test of this hypothesis would compare the frequencies of aberrant snakes in multiple populations across the geographic range of *T. sirtalis*, and test whether these frequencies differ across a latitudinal or longitudinal gradient. Such an approach is not feasible at the present time; the number of records of albinism and leucism we found was too small (Table 1) to generate reliable calculations of aberrant morph frequencies per population (or even per museum). Instead, we simply compared the latitude and longitude of albinos to those of wild-type snakes from a search of museum records. This approach has its own drawbacks: for example, it assumes wild-type specimens are collected or observed at a given locality in direct proportion to their frequency in natural populations, and that albino specimens would be noted as such in HerpNet2, which is clearly not always the case. Nevertheless, this approach offers, in our view, a reasonable starting point to address this question.

All else being equal, we expected that if albinos are encountered at higher frequencies in the northern part of their range as compared with elsewhere—assuming that any such observation bias corresponds to true differences in the frequency of albinism—we would find that the number of observations of albinos was skewed in this direction. The peak number of observations was centered at around 40° N (Fig. 1A), roughly the central part of their latitudinal range (Rossman et al. 1996). However, there was no difference in the median latitude of albinos and wild-type snakes, and the distribution of wild-type snakes in the HerpNet2 database corresponds closely with that of albinos. Thus, we find no support for the hypothesis of a latitudinal gradient of albinism per se, though limited sampling in the northern and southern parts of its range could conceivably obscure a real pattern. It is also conceivable that albinos are more strongly selected against at relatively high and low latitudes, and are more abundant at around 40°N, but distinguishing between this possibility and observer bias is not presently possible.

The peak distribution of albino and leucistic *T. sirtalis* was centered around -80°E, with two observations much further west (Fig. 2A). There was a difference in the median longitude of albinos and wild-type snakes, with putative wild-type snakes found further west than albinos. Common Garter Snakes are largely absent from the major deserts of the western and southwestern US (Rossman et al. 1996), and the comparatively small number of records in HerpNet2 of *T. sirtalis* found at sites between the Great Plains and western Nevada found is not unexpected (data not shown). However, it is notable that we found no records for albino *T. sirtalis* from California specifically, despite the large number of records from that state with latitude/

longitude data in the HerpNet2 database (2293/9823 specimens from California, or 23% of the total).

Summary and future directions.—Is there a geographic bias in the occurrence of albino *T. sirtalis*? We found no evidence for a latitudinal bias in observations, but did find evidence of a possible longitudinal bias. If this pattern reflects a real biological phenomenon, perhaps the paucity of albino *T. sirtalis* records from the west reflects underlying differences in thermal, climatic, or predator regimes in western habitats, as compared with those elsewhere in its range.

We caution, however, that there are many possible alternative explanations for this pattern. For example, a small observation/ collection rate of albinos at sites in the west might reflect local behavioral plasticity; as one possibility, adoption of crepuscular or nocturnal activity by albinos could conceivably lower detection rates at a given site, even if the frequency of albinos is unchanged. Alternatively, perhaps the majority of western specimens have been collected under study designs that either advertently or inadvertently tended to minimize the chance of encountering (or capturing) aberrant snakes. In addition to collection or observer bias, perhaps museums holding the majority of western specimens of *T. sirtalis* tended to omit supplemental information about a given specimen (such as possible color anomalies) when data were uploaded to HerpNet2. This possibility underscores the importance of direct inspection of individual specimens whenever possible (Krecsák 2008).

Determining which of these factors, if any, is responsible for the limited number of observations of aberrant *T. sirtalis* in the western part of its range represents a significant challenge. However, testing the hypothesis of a longitudinal (or latitudinal) bias might be more feasible in the context of a larger cross-species study. As a possible starting point, we note that albinism has been reported from at least four species of garter snake that have ranges that extend into California (*T. sirtalis*, *T. elegans*, *T. marcianus*, *T. ordinoides*, Tables 1–2; Rossman et al. 1996), but for which we found no confirmation of albinism from any record within that state, either within the literature or in the HerpNet2 database.

More generally, data on color aberrancies from studies of Common Garter Snakes in the north, south and western parts of the range of *T. sirtalis* are needed to provide a better sense of whether the apparent absence of albinos from these areas has a real biological basis. Inspection of individual preserved snakes is also likely to reveal additional specimens not reported here. It is also possible that some reports describing “albinism” in *T. sirtalis* conflated albinism (sensu Bechtel 1995) with other color aberrancies, and inspection of older preserved specimens to confirm and/or reassess aberrant color status is recommended for future studies. Despite the limitations inherent in the approach described here, we believe that we have made steps towards a rigorous analysis of geographic variation in albinism and its possible functional significance.

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