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Ophidiophobia, myth generation, and human perceptions: Implications for snake conservation in a typical savanna community of northern Ghana

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ABSTRACT

Snakes have fascinated and terrified humans throughout history. Worldwide, innate fear (ophidiophobia), culturally-founded superstition, and myths have caused pervasive snake persecution, snakebite mismanagement, human injuries, and fatalities, particularly in the tropics. We analyzed 20 common snake myths narrated by 934 respondents inhabiting a typical rural savanna community of northern Ghana. The myths summarized perceived, self-assessed knowledge about snakes and were evaluated in their zoo-ecological contexts versus their folkloristic explanatory origins. Only eight snake myths (~40%) had any justifiable scientific basis, partially representing misinterpretations among predominantly male, less-educated respondents. Contrastingly, 70% of the myths were largely rooted in ophidiophobia, representing a major driver of human-wildlife conflict and indiscriminate snake persecution. To promote wildlife-friendly perceptions and behavior toward snakes and their conservation, we recommend innovative gap-bridging conservation education and public awareness that reconciles myths and realities about snakes, thus reducing snakebite incidences, mortality, and widespread persecution and killing of snakes.

KEYWORDS

Beliefs; folklore; psychology; self-assessed knowledge; snake fear; West Africa; zoo-ecology

Introduction

Hominins and animals have co-evolved worldwide, thereby developing strong competitive, predator-prey, mutual, and utilitarian relationships for millions of years (Reperant et al., 2012; Shipman, 2010). Based on such sympatric interactions, and since human communication began (Morgan et al., 2015; Sterelny, 2012), human-animal connections initially generated pictorially/symbolically (Morris-Kay, 2010; Shipman, 2010) and verbal (Coen, 2019; Kolodny & Edelman, 2018) traditions, some of which were refined and transformed into culturally-determined folkloristic narratives, including tales, anecdotes, and myths (Coen, 2019; Sax, 2001). Myths have often originated, thrived, and been maintained around particular faunal groups, due to either beneficial (Morelli et al., 2015) or maligned (Daujeard et al., 2016) anthro-zoological interfaces (Sax, 1999, 2001). Animal myths are, therefore, particularly prevalent about humankind's main predators (e.g., Campbell & Pile, 2011), as well as other dangerous aquatic or terrestrial animals, including a variety of poisonous or venomous taxa (Sax, 2001).

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Animal myths are probably founded psychologically in undue fear (phobia), disgust, fascination, and wonder (Campbell & Pile, 2011; Sax, 1999), and are found across all cultures globally (Sax, 2001). However, constituting universal human psychological traits with largely emotional-irrational bases, horrifying myths, and aversive misconceptions about animals may also have extensive consequences for behaviors and attitudes toward animals across modern-day societies, as related to demography, cultural history, intellect, and educational background (Boafo et al., 2016; Jacobs, 2009). Consequently, some animal myths have implications for human-wildlife conflicts and wildlife conservation, particularly for vulnerable fauna in diverse biomes, including tropical areas (C. Hughes, 2013; Onyishi et al., 2021). Conversely, animal myths and storytelling may also play vital roles in how human societies recognize, develop, and maintain respect or disrespect for animals (Appiah-Opoku, 2007; Onyishi et al., 2021), including fauna perceived as dangerous, disgusting, or terrifying (C. Hughes, 2013).

Efforts should bridge the gap between myth and reality storytelling, explicitly between folkloristic daily-life emotions and scientific rational thinking (Coen, 2019; Sugiyama, 2017). Such efforts may facilitate conservation actions in the form of public education, awareness creation, and information dissemination (Fernández-Llamazares & Cabeza, 2018; De Groot & Zwaal, 2007). Research into the anthro-zoological relationships between myths and human-wildlife conflicts is, therefore, essential for conservationists, wildlife managers, and educators (Fernández-Llamazares & Cabeza, 2018; C. Hughes, 2013), as well as for basic human self-understanding (Coen, 2019; Sax, 1999). In our context, this type of research is also essential for understanding the biocultural evolutionary trajectory of human conscience, intelligence, and phobia, which are underpinned by natural selection principles (Clasen, 2012; Isbell, 2006) and psychological theories of cognitive and associative learning (Asma, 2014; Baynes-Rock, 2017).

Harmful or not, snakes represent a prime fear-inducing taxon (Baynes-Rock, 2017; Polák et al., 2016), with population frequency of fear of snakes (ophidiophobia) at ~5% (Rádlová et al., 2020) that is proportionately higher in females (Fredrikson et al., 1997; Rakison, 2009). Ancient cultures and modern societies have invariably harbored misconceptions and myths about this aversive faunal group, which is a source of human-wildlife conflicts worldwide (Pandey et al., 2016; Warrell, 2010). Globally, snakes have been persecuted pervasively (Langley et al., 1989; Whitaker & Shine, 2000), being often misunderstood and maligned, primarily due to lack of awareness about their true nature and position in the natural world (Öhman & Mineka, 2003; Wojnowski, 2010). Snakes are important controllers of agricultural pests and key links within complex food webs of both aquatic and terrestrial ecosystems (Stanley, 2008; Valencia-Aguilar et al., 2013). Contrary to popular belief, snakes do not attack humans unprovoked and are often more wary of humans than vice-versa (Ménez, 2003; Whitaker & Shine, 2000), yet are often misconceived as ultimately lethal, and thus are often instantly killed on sight (Langley et al., 1989; Pandey et al., 2016). The densities of sympatric populations of snakes and humans have been on the increase in many rapidly expanding peri-urban and agricultural landscapes across the tropics (Böhm et al., 2013), including the African continent (Wojnowski, 2010). As such, rapid urbanization, habitat destruction, antipathy, and misconceptions about snakes could all lead to the ultimate extirpation of vulnerable species (Baynes-Rock, 2017; Wojnowski, 2010).

Viewed on a continuum, the fear of snakes at the lowest end of the scale constitutes ambivalent, but rational mixed emotions of fascination and cautious respect, but this rises

toward antipathy and disgust, and then culminates in a neurotic and often irrational ophidiophobia (Landová et al., 2020; Ptáčková et al., 2017). Humans and other primates may have evolved instinctive (Isbell, 2006) or genetically-predisposed, but culturally acquired and augmented ophidiophobia (Kawai, 2019; LoBue & DeLoache, 2008). Contemporary theories of both 'snake detection' (Isbell, 2006) and 'preparedness' (Öhman & Mineka, 2003; Seligman, 1971) would predict that pervasive ophidiophobia, whether exclusively innate (Bertels et al., 2020) or cognitively-conditioned (Murray & Foote, 1979; Rachman, 1977), is likely to be more prevalent in nature-bound cultures found in the warm and humid tropics. Such societies consist largely of hunter-gatherers or agriculturists who have evolved alongside, and thus been exposed to, an abundant and rich snake fauna (Baynes-Rock, 2017). Snake stories and myths, primarily driven by fear of or disgust for snakes, may thus be a complementary means of biocultural evolution (Murray & Foote, 1979; Onyishi et al., 2021). The generation and persistence of myths about snakes might function as indirect ways of vicariously conditioning potential victims of snakes, either as prey or for envenomation. Myths rooted in fear may refine and promote extra alertness or associative preparedness, not conditioned contingencies (Flykt, 2006; Murray & Foote, 1979; Seligman, 1971) when moving in habitats particularly rich in snakes. This further enhances detection of the potential lethal danger when stepping on, reaching out, or grabbing serpent-like objects (Baynes-Rock, 2017; Isbell, 2006; Öhman & Mineka, 2003). Being conscious about a real danger, augmented by ophidiophobia-triggered or exaggerative snake myths, may increase the preparedness for potential encounters, and thus also enhance the detectability by refining the acuteness of ones visual detection (Kawai & Qiu, 2020; Rádlová et al., 2020). This could be both in terms of coil-like or wriggling objects, or disintegrating snake body camouflaging traits in areas with dense litter, twines, and grass (Baynes-Rock, 2017; Isbell, 2006).

Tropical environments are epicenters for negative human-serpent encounters (Warrell, 2010), particularly on the rural and resource-starved African continent where snakebites are frequent (Chippaux et al., 2015), myths are common (Hambly, 1931), and severe snake persecution is the norm (Attuquayefio, 2004; Onyishi et al., 2021). Northern Ghana, for example, records a rich snake fauna, frequent snakebites, and a diverse snake folklore (Musah et al., 2019), for which anecdotes, beliefs, and misconceptions may derive from negative human-snake conflicts transferred by oral tradition (Anquandah, 2013; Attuquayefio, 2004). In many parts of Africa, low literacy and information levels of the populace, educated or not (Wojnowski, 2009, 2010), may further contribute to the mystification of snakes and deepened the lack of knowledge about their true nature. Misconceptions and negative perceptions that compromise snake conservation goals often have colonial connotations in their origin (Tropp, 2003).

Our study aimed to identify common snake myths and their prevalence among inhabitants of a typical rural savanna community in northern Ghana where both the snake fauna and snakebite epidemiology are fairly well-known (Musah et al., 2019). A major objective was to document and evaluate predominant misconceptions, either self-assessed or mythologically-founded, versus factual knowledge about snakes. Although initially not a prime focus of our study, we also proposed to view the knowledge, myths, and perceptions about snakes in a holistic human-serpent context of a reciprocal predator-prey evolutionary arms race, with an etiological focus on contemporary anthropological-psychological and cognitive versus innate theories of fear-conditioning, associative preparedness, and visual detection of snakes (Baynes-Rock, 2017).

Such information is essential for developing new educational strategies to reduce human-snake conflicts, minimize snakebite incidents and fatalities, and prevent the indiscriminate killing of snakes (Onyishi et al., 2021; Wojnowski, 2009, 2010). We hypothesized that the majority of snake myths represent nonscientific misconceptions, basically founded in ophidiophobia, for which many unconsciously may function to improve snake detection through vicariously-conditioned preparedness toward negative snake encounters. We also hypothesized that such phobic misconceptions are related to demographic characteristics such as gender, age, education level, and occupation, and that both fear and misconceptions about snakes are undermining progressive snake conservation initiatives in Northern Ghana. Finally, we sought to recommend innovative conservation measures and actions directed against the prevalent and environmentally-unsustainable human perceptions and behavior toward snakes.

Methods

Study Area

Our study was conducted in the former Savelugu-Nanton District (now two separate districts) in northern Ghana, where the lead author is a native and thus had detailed insight into ethnicity and other demographic traits. The district encompassed ~2,023 km^2, abutting West Mamprusi, Karaga, Tolon, and Kumbungu Districts, and the Tamale Metropolitan Area (Figure 1). The area is demographically representative of a typical rural agrarian community in the Guinea Savanna vegetation zone of West Africa. Rainfall pattern is unimodal and erratic, ranging from ~600 mm to 1,000 mm annually, with a mean temperature of 34°C, (ranging between >42°C and <15°C). Estimated human population density (2008–2009) was ~64 km^{-2} (Musah et al., 2019). Typical ethnic groups are the Bimoba, Dagomba, Gonja, Konkomba, Mamprusi, and Nanumba. We surveyed seven townships with public healthcare facilities: Savelugu (district capital), Nanton, Tampion, Moglaa, Diarre, Pong-Tamale, and Zoggu (Figure 1). These locations were representative of small, medium, and large settlements, reflecting various urban segments of the population (Musah et al., 2019). The sparsely-populated northern parts of the district had dense woodland vegetation, whereas the urbanized southern part around Tamale was characterized by intensive farming, bush burning, and fuelwood harvesting.

Study design and data sampling

We conducted a six-month cross-sectional respondent study between December 2008 and May 2009 in the Savelugu-Nanton District. One thousand inhabitants were subjected to *a priori* developed, semi-structured, independently-administered, face-to-face questionnaires, adjusted on an *ad hoc* basis. The questionnaire formed the last part of a series of prior questions on snake encounters, epidemiology, and ecology (Musah et al., 2019). The questions were open-ended and served to identify self-assessed knowledge and perceptions about snakes from respondents' own experiences or by learned narratives from others. Example questions included "*What do you know about snakes, and what stories have you heard about them*." As an indigenous person, the lead author was already familiar with three common narratives (see myths 1, 11, 17 in Table 1), and if necessary, often initiated the

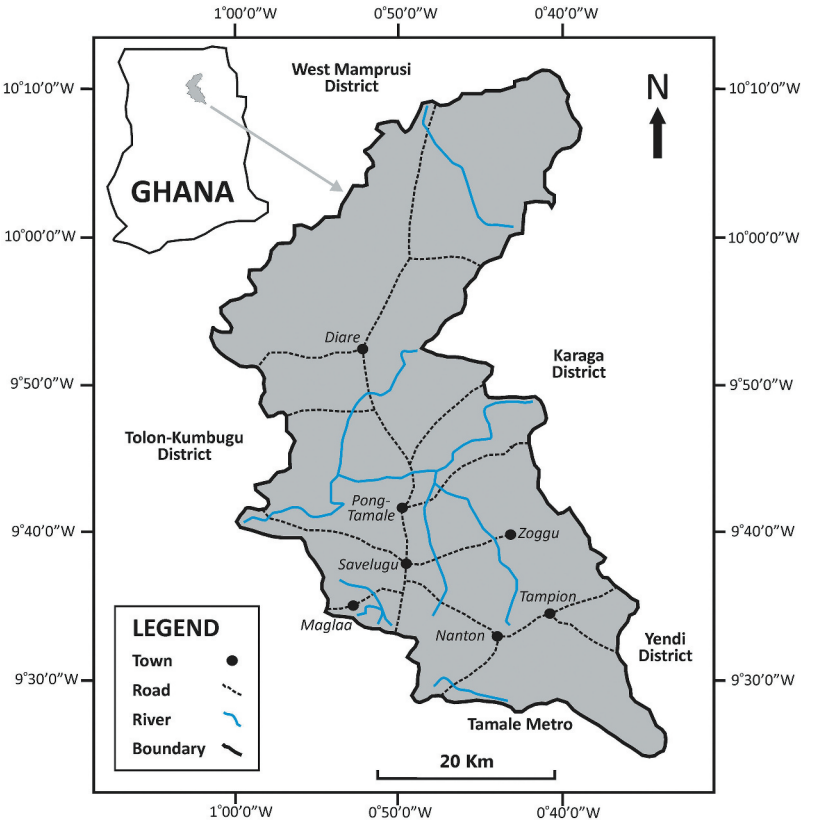

Figure 1. Map of the Savelugu-Nanton District in northern Ghana, showing major roads, rivers, and the seven selected townships for the study.

conversation by asking if a respondent had knowledge of any of these three narratives. No other narrative was revealed methodically this way.

The sample of 1,000 respondents in our study was stratified across three age groups, each with equal gender composition; >30 years (n = 400), 15–30 years (n = 300), 8–15 years (n= 300), reflecting three demographic groups: (a) elders and family heads, (b) actively farming youth, and (c) dependent children. The older group constituted a slightly higher proportion due to their anticipated higher encounter frequency and ability to provide more precise and perceptive information. Minors were involved to assess any generational myth transmission and they were always interviewed in the presence of their parents, guardians, or other mature family members. The numbers of residents sampled from each of the seven study sites were proportional based on size: Savelugu (n = 200), Diarre and Pong-Tamale (n = 150 each), and Nanton, Zoggu, Moglaa, and Tampion (n = 125 each). Within each of these seven communities, household units were selected on *ad hoc* basis, conforming to the gender-age stratification criteria (Musah et al., 2019). The selection involved consecutive enumeration of units in a sequence and adoption of an arbitrary criterion of minimum and maximum distances of ~25-50 m and ~50-100 m, respectively. Longer distances were maintained among units in the sparsely-populated community fringes with narrower selection in

Table 1. Topic and main narrative of the 20 most common snake myths identified among the 934 respondents.

#	Topic	Main narrative
1	*"Snakes obtain venom from frogs and toads"*	Snakes are perceived to extract venom from frogs and toads for their own use, as anurans are often seen being pursued or swallowed by snakes.
2	*"After a bite, snake fangs break off and get lodged in the wounds of their victims"*	Snake fangs are often perceived to be fragile, thus easily break off and embed in a snakebite victim's body and are therefore apparently not visible in the snake's mouth after a bite.
3	*"Snakes can bite and sting with both their tongues and tails"*	The repeated flicking of the forked tongue is perceived as the snake attempting to bite with it, and their often actively moving tails are also thought to be used as stingers similar to those found in scorpions.
4	*"The body and skeleton of live or dead snakes are poisonous"*	It is believed that stepping on the body or skeleton of a snake, dead or alive, could result in poisoning or death, since all snakes are poisonous.
5	*"All slender black or dark snakes are cobras"*	All black or dark-brown colored snakes are generalized as cobras, hence considered extremely dangerous and overly feared.
6	*"All cobras can spit venom"*	There is a general perception that all cobras are capable of spitting venom, and therefore the most feared among all snakes.
7	*"Some snakes fly and crow like cocks"*	Snakes with horny scales or projections on the snout are thought to resemble crowing cocks, and are therefore thought also to have flying ability.
8	*"Some snakes lash victims painfully with their tails"*	Some long and slender snakes may have a whip-like appearance which often elicits fear and panic in people who perceive them to be always on the lookout for humans to lash.
9	*"Some snakes move fast enough to outrun humans"*	Some swift snakes (e.g., cobras, sand racers) are believed to outrun humans when these are chasing them.
10	*"Some venomous snakes are blind and aggressive"*	The uncontrolled strike-behavior of some snakes when provoked, cornered or taken by surprise, creates the impression of snakes being blind.
11	*"Death will inevitably occur if snake venom is spat into the nose of a victim"*	The general observation that venom spat by spitting cobras may lead to blindness in a victim, has been extended to another part of the face, the nasal opening.
12	*"Urine from a victim can cure eye damage from venom-spitting snakes"*	The knowledge that quick application of water or any aqueous solution could minimize eye damage in a victim of a cobra spitting, has been extended to urine as a substitute for water.
13	*"Some snakes are dangerous to pick up even when dead"*	The belief is, reportedly, that a dead gravid snake carries live offspring that will emerge through its skin and bite the person to defend and revenge their dead mother.
14	*"Puff adders bury themselves in sand to heal after giving birth to live young"*	It is commonly believed that unborn puff adder offspring bite through the mother's belly, and the female subsequently buries her body in sand for the resulting skin wounds to heal.
15	*"Some rapid and swift snakes may turn around and chase their human pursuers"*	It is believed that some fierce snakes may attempt to face and even counter-attack their human pursuers very aggressively.
16	*"To avoid dying, snakes never return to a previous skin-shedding location"*	Snakes are occasionally found lying dead next to their shed skins, wherefore it is believed that it is dangerous for the snake to revisit such a location.
17	*"Pythons break the bones of their victims before swallowing them"*	It is generally perceived that in order for pythons to swallow prey, they need to crush the bones first to soften the body and make swallowing easier.
18	*"Pythons swallow their prey legs first"*	It is often believed that the relatively smaller legs of prey are much easier to swallow than the large head.
19	*"Pythons have to smear their prey with saliva before swallowing them"*	Pythons swallow very large prey relative to their size, so it is a common belief that prior smearing of saliva on the prey is needed to reduce friction during swallowing.
20	*"Pythons are killed faster when their head to tail breathing cycle reaches the tail"*	The general belief is that breathing movements in snakes occur in cycles from head to tail, thus pythons become unconscious when the breathing cycle reaches the tail-end, with the head end devoid of air, hence making it easier to kill.

the densely-populated community centers (Musah et al., 2019). Respondents were interviewed on their premises, workplace, or farms.

The Ethical Committee, led by the Head of the Department of Animal Biology and Conservation Science at the University of Ghana, approved the research as conforming to national ethical standards. The lead author presented an explanatory letter of introduction to local authorities. As such, prior informed consent (PIC) was obtained from community assembly members, supported by explanations of the scope, purpose, and practice of the study to participating elders and other family heads. Systematic interview protocols and PIC enhance reliability and inclusiveness of respondent information, as well as the quantity and quality of data.

Describing and Categorizing Myths: Biological Significance and Conservation Implications

We aimed to describe common snake perceptions and narratives based on respondents' self-assessed knowledge about snakes, which enabled us to evaluate the biological significance and scientific basis of local awareness regarding behavioral ecology, physiology, and venom toxicology, with particular reference to ophidiophobia and conservation implications related to wildlife conflict. Based on the accumulated self-assessed knowledge, experiences, perceptions, and stories reported among respondents, we summarized these into the 20 most common, specifically-recognizable and similar narratives, which we subsequently identified and termed "myths" (Table 1). Using this categorization, we were able to evaluate the prevalence of these myths among the local community in relation to gender, age, and education level. Such information is key to the subsequent development of strategies for formal and informal conservation education on snake biology in relation to human-wildlife conflict and fear of snakes.

Statistical Analysis: Myth Prevalence in Relation to Gender, Age and Educational Level

For each of the identified myths, the percentage distribution relative to gender, age, and education level were compared with the overall equivalent respondent profile (n = 1,000 respondents) and tested for significant differences among groups. We used Fisher's exact test for 2 × 2 contingency tables (two genders compared), or χ^2 G-test for three (2 × 3 for age) or four (2 × 4 for education level) groups compared, with significance level set at $p < .05$, df = 1–3 (Musah et al., 2019). We were thus able to detect the prevalence of each myth among subsets of the local communities with regards to gender, age, and education. We used Social Science Statistics (https://www.socscistatistics.com/tests/) to perform these statistical tests.

Results

Snake Myths: Frequency, Biological Significance, Scientific Basis, and Human Conflicts

Among the 20 common snake myths recorded, 13 (~65%) focused on physiology, 12 (~60%) focused on behavior, five (~25%) focused on both of these, and four (~20%) focused

Table 2. Twenty snake myths with their biological significance, scientific basis, and conservation implications, ranked according to the level of familiarity.

Myth #	Total (%) [a] respondents	Biological Significance			Scientific basis	Conservation Implications		
		Behavior	Physiology	Toxicology		Bite	Fear	Conflict
1	934 (93.4)		x	x	Yes			
4	934 (93.4)		x	x	No		x	
11	934 (93.4)		x	x	Yes		x	x
17	934 (93.4)	x	x		Yes		x	
2	924 (92.4)		x		No	x	x	
12	920 (92.0)		x	x	Yes			
9	910 (91.0)		x		No		x	
5	900 (90.0)		x		No		x	
20	810 (81.0)		x		No		x	x
18	684 (68.4)	x			Yes			
13	617 (61.7)	x			Yes		x	x
10	500 (50.0)	x	x		No		x	x
19	500 (50.0)	x	x		Yes			
3	451 (45.1)	x	x		No	x	x	x
6	450 (45.0)	x	x		No		x	x
15	358 (35.8)	x			Yes		x	x
14	250 (25.0)	x			No			
7	200 (20.0)	x			No		x	
16	113 (11.3)	x			No			
8	10 (1.0)	x			No		x	x
Total		12 (60)	13 (65)	4 (20)	Yes = 8 (40)	2 (10)	14 (70)	8 (40)

[a]Numbers in brackets are percent of total number of myths.

on venom toxicology (Tables 1, 2). Only eight (~40%) myths had any known scientific basis with the rest arising from superstition and anecdotal beliefs. Although 40% had a partial scientific basis, the majority of reported snake perceptions were scientifically unsubstantiated. As many as 70% of the myths were related to fear of snakes (ophidiophobia), followed by fear and conflict combined (40%), conflict alone (40%), and snakebites (10%; Table 2). Of the 1,000 respondents, 81–93% were familiar with nine myths (1, 2, 4, 5, 9, 11, 12, 17, 20), 36–68% were familiar with seven myths (3, 6, 10, 13, 15, 18, 19), and 1–25% were familiar with four myths (7, 8, 14, 16; Table 2). The four least frequently known myths were also mostly associated with perceptions of snakes as having supernatural capabilities.

Prevalence of Snake Myths in Relation to Gender, Age, and Education Level

Of the 1,000 interviewees, 934 (~93%) had knowledge about snake myths and the overall respondent profile (n = 1,000) was 500–500 (50%, 50%) for gender (M, F), 400–300-300 (40%, 30%, 30%) for the three age groups (>30, 15–30, 8–15, yrs), and 518–439-39-4 (52%, 44%, 4%, <1%) for the four education groups (None, Basic, Secondary, Tertiary; Table 3). Men were proportionately and significantly more represented in nine myths (7, 10, 13, 14, 15, 16, 18, 19, 20) than women, the latter being under-represented in all 20 myths (Table 3). The >30 years age group was significantly prevalent in seven myths (10, 13, 14, 16, 18, 19, 20), with only one predominant myth each for the age groups 15–30 years (3) and 8–15 years (6; Table 3). Respondents without formal education dominated in four myths (3, 13, 18, 19), whereas those with basic education and those with secondary education dominated in two myths each (10, 15 and 7, 16, respectively). There was under-representation of respondents with tertiary education for all 20 myths (Table 3). Overall,

Table 3. Distribution of gender, age, and education level among 1,000 respondents familiar with 20 snake myths.

	Gender (%) [a]			Age Group (%) [a]				Educational Level (%) [a]					Total
Myth #	M	F	p-value [b, c]	>30	15–30	8–15	p-value [b, c]	None	Basic	Secondary	Tertiary	p-value [b, c]	(% of 1000)
1	490 (52)	444 (48)	0.279	394 (42)	280 (30)	260 (28)	0.511	491 (53)	400 (43)	39 (4)	4 (<1)	0.963	934 (93.4)
2	490 (53)	434 (47)	0.184	388 (42)	277 (30)	259 (28)	0.575	488 (53)	399 (43)	35 (4)	2 (<1)	0.877	924 (92.4)
3	225 (50)	226 (50)	0.969	150 (33)	151 (34)	150 (33)	**0.0497**	300 (67)	149 (33)	2 (<1)	0 (0)	**<0.0001**	451 (45.1)
4	490 (52)	444 (48)	0.279	394 (42)	280 (30)	260 (28)	0.511	491 (53)	400 (43)	39 (4)	4 (<1)	0.963	934 (93.4)
5	485 (54)	415 (46)	0.090	384 (42)	266 (30)	250 (28)	0.437	475 (53)	384 (42)	37 ()	4 (<1)	0.955	900 (90.0)
6	225 (50)	225 (50)	1.000	110 (25)	150 (33)	190 (42)	**< 0.0001**	200 (50)[d]	169 (42)[d]	29 (7)[d]	2 (1)[d]	0.710	450 (45.0)
7	180 (90)	20 (10)	**< 0.0001**	70 (35)	70 (35)	60 (30)	0.299	86 (43)	80 (40)	32 (16)	2 (1)	**<0.0001**	200 (20.0)
8	10 (100)	0 (0)	-	6 (60)	3 (30)	1 (10)	0.314	5 (50)	4 (40)	1 (10)	0 (0)	0.677	10 (1.0)
9	489 (54)	421 (46)	0.103	382 (42)	273 (30)	255 (28)	0.578	482 (53)	390 (43)	35 (4)	3 (<1)	0.9579	910 (91.0)
10	485 (97)	15 (3)	**< 0.0001**	392 (78)	100 (20)	8 (2)	**< 0.0001**	144 (29)	350 (70)	4 (1)	2 (<1)	**<0.0001**	500 (50.0)
11	490 (52)	444 (48)	0.279	394 (42)	280 (30)	260 (28)	0.511	491 (53)	400 (43)	39 (4)	4 (<1)	0.963	934 (93.4)
12	490 (53)	430 (47)	0.153	394 (43)	276 (30)	250 (27)	0.323	480 (52)	398 (43)	38 (4)	4 (<1)	0.987	920 (92.0)
13	488 (79)	129 (21)	**< 0.0001**	300 (49)	186 (30)	131 (21)	**0.000154**	385 (62)	200 (33)	30 (5)	2 (<1)	**<0.0001**	617 (61.7)
14	240 (96)	10 (4)	**< 0.0001**	238 (95)	10 (4)	2 (1)	**< 0.0001**	121 (49)	123 (49)	5 (2)	1 (<1)	0.289	250 (25.0)
15	306 (85)	52 (15)	**< 0.0001**	118 (33)	119 (33)	121 (34)	0.0624	150 (42)	177 (50)	30 (8)	1 (<1)	**0.000543**	358 (35.8)
16	98 (87)	15 (13)	**< 0.0001**	66 (58)	33 (29)	14 (13)	**0.000061**	45 (40)	45 (40)	23 (20)	0 (0)	**<0.0001**	113 (11.3)
17	490 (52)	444 (48)	0.279	394 (42)	280 (30)	260 (28)	0.511	491 (53)	400 (43)	39 (4)	4 (<1)	0.963	934 (93.4)
18	400 (58)	284 (42)	**0.0006**	384 (56)	200 (29)	100 (15)	**< 0.0001**	485 (71)	180 (26)	18 (3)	1 (<1)	**<0.0001**	684 (68.4)
19	487 (97)	13 (3)	**< 0.0001**	284 (57)	116 (23)	100 (20)	**< 0.0001**	440 (88)	55 (11)	5 (1)	0 (0)	**<0.0001**	500 (50.0)
20	460 (57)	350 (43)	**0.0040**	388 (48)	242 (30)	180 (22)	**< 0.0001**	427 (53)	350 (43)	31 (4)	2 (<1)	0.931	810 (81.0)
RP	500 (50)	500 (50)	-	400 (40)	300 (30)	300 (30)	-	518 (51.8)	439 (43.9)	39 (3.9)	4 (0.4)	-	1000 (100.0)

[a]Bracketed figures refer to respondents with knowledge on a particular myth relative to the total number of respondents (%).
[b]*p*-values refer to χ^2-test for comparison between each myth and the total respondent profile (RP).
[c]Statistically significant values in bold.
[d]Total for educational level = 400.

prevalence of myth knowledge was inversely related to education level. Older men and those least educated were most knowledgeable regarding snake myths, particularly for Myths 7, 10, 13, 14, 15, 16 and 18, 19, 20, respectively (Table 3).

Discussion

Origin and Explanations of Snake Myths in Northern Ghana: The Science and Reality

We identified 20 commonly-known snake myths in northern Ghana, mostly focusing on snake physiology, behavioral ecology, and venom toxicology. Below, we evaluate the 20 myths with respect to their possible explanatory origins in contrast with current scientific facts.

Myth 1: "Snakes Obtain Venom from Frogs and Toads"

Snake venom is modified saliva, mostly used for immobilizing and digesting prey (Casewell et al., 2013), and for defense (Spawls & Branch, 1995). Frogs or toads (anurans) are often prey for many snakes in northern Ghana (e.g., Spotted night adder [*Causus maculatus*]; Ineich et al., 2006). Snakes are vulnerable when swallowing prey, and if disturbed, disgorge the slimy enzyme-laden saliva-smeared prey, thus creating a misconception of the snake extracting poison from the prey (Marais, 2014). Some non-venomous snakes prey on anurans and this is unrelated to poison extraction (Attuquayefio, 2004). Few venomous snakes sequester toxins from their prey for defense (Savitzky et al., 2012), a phenomenon unknown in northern Ghana snakes. Some snakes can detect the poison of prey, so avoid them (Muscat & De Toledo Moroti, 2018).

Myth 2: "After a Bite, Snake Fangs Break off and Get Lodged in the Wounds of Their Victims"

Snakes are classified according to the presence, absence, modification, and position of their fangs. A typical inhabitant of northern Ghana, wrongly believing that all snakes are venomous and front-fanged (i.e., a sign of fear), would expect to see fangs of a snake captured or killed after biting a victim. The apparent lack of fangs in some snake species could be because they are back-fanged, not because their broken-off fang had been lodged in the victim's wound. Back-fangs are hidden behind the row of teeth and are, therefore, not easily observable to a layperson. Although snake fangs are shed or replaced periodically, they rarely break and embed in the tissue of victims (Tyagi & Whyte, 2014) due to their retractile and flexible nature.

Myth 3: "Snakes Can Bite and Sting with Both Their Tongues and Tails"

The flicking snake tongue serves both olfactory and gustatory functions, whereas the tail is locomotory and prehensile (Attuquayefio, 2004). Tongues and tails of snakes are too fleshy for use as injecting organs; the sharp fangs are the sole envenomation organ of all venomous snakes. This myth may have originated from observing other venomous animals such as scorpions or bees sting with their tails or rear end, unlike the head location of snake fangs

and venom glands. When stepped on, the speed at which snakes strike may also create an impression that both their head and tail can envenomate, and thus an indication of undue fear of snakes (ophidiophobia).

Myth 4: "The Body and Skeleton of Live or Dead Snakes are Poisonous"

Despite the clear distinction between *poison* (skin or tissue gland secretions that are harmful when consumed, inhaled, or absorbed) and *venom* (derived salivary gland secretions that are harmful when injected into the blood or tissue, or sprayed into eyes), these terms are often used interchangeably (Weinstein, 2015). Snakes envenom their prey to subdue it, whereas poisonous animals are harmful when consumed or touched. Venom is stored in a small modified salivary gland connected to the fangs by the venom duct. The rest of the snake's body is completely harmless in a live or dead venomous snake. Stepping on a snake skeleton may cause skin puncture leading to microbial infections without proper treatment, which probably instigated the 'poisonous snake skeleton' myth, thus a myth rooted overly in fear of snakes.

Myth 5: "All Slender Black or Dark Snakes are Cobras"

The seven cobra species in Ghana (Uetz et al., 2021) are black (Black-necked spitting cobra *Naja nigricollis*; Black forest cobra *N. guineensis*; West African banded cobra *N. savanulla*, Black tree cobra *Pseudohaje nigra*; Gold's tree cobra *P. goldii*) or dark brown (Katian spitting cobra *N. katiensis*; Senegalese cobra *N. senegalensis*). This may have led to a misconception that all black or dark and long snakes are cobras, so are venomous, front-fanged, and dangerous, eliciting typical ophidiophobia. Other black or brownish snakes live in northern Ghana (B. Hughes, 1988), but are not cobras, such as the venomous back-fanged Blanding's tree snake *Toxicodryas blandingi* and Western glossy snake *Amblyodipsas unicolor*, and the non-venomous African house snake *Lamprophis fuliginosus* and back-fanged Red-lipped snake *Crotaphopeltis hotamboeia.*

Myth 6: "All Cobras Can Spit Venom"

Only two cobra species in Ghana are spitters due to a special anatomical adaptation of their front-fixed fangs (the Black-necked spitting cobra and Katian spitting cobra) and these are usually blackish or dark-brownish, respectively (B. Hughes, 1988). As other cobras in Ghana have similar colors, the venom-spitting trait is applied to all venomous snakes, sometimes including even non-venomous ones. This myth is indicative of exaggeration related to fear of snakes.

Myth 7: "Some Snakes Fly and Crow like Cocks"

The horny protruding scales or scaly projections on the snout, eye lining, and head of vipers and adders in Ghana (Gaboon viper *Bitis gabonica*; Rhinoceros viper *B. nasicornis*; Puff adder *Bitis arietans*) resemble the combs of cocks. Viperid snakes occasionally make loud hissing or puffing sounds considered reminiscent of cock crowing by the locals, and as cocks are birds, such snakes are ascribed some flying ability. The reality is that no snake is capable of true flight, but limited to only short-distance gliding, such as when leaping between tree

crowns (Socha et al., 2010). This perception of snakes' 'supernatural' capabilities reflects undue fear.

Myth 8: "Some Snakes Lash Victims Painfully with Their Tails"

Many arboreal snakes possess long, slender bodies and tails (e.g., Green mamba *Dendroaspis viridis* and Twig snake *Thelothornis kirtlandii*), which may brush against a passerby when the snakes hang loosely from tree branches. Such encounters often elicit fear and panic (ophidiophobia), fueled by the misconception that the snakes purposely lash victims with their tails. Likewise, the side-to-side tail slashing during rapid locomotion may also create a false perception of snakes lashing people. The North American Coachwhip snake *Masticophis flagellum* is believed to lethally lash human victims with its long and braided whip-tail, a myth that is inconsistent with its naturally placid and non-aggressive behavior (Stanley, 2008), including death-feigning (Gehlbach, 1970).

Myth 9: "Some Snakes Move Fast Enough to Outrun Humans"

Snake locomotion involves both sideways bending and contortions with little forward progression (Jayne, 2020). Most snakes are thus capable of low speeds between 3.2–9.6 km/h, reaching the fastest at 19.2–22.4 km/h (e.g., Black mamba *Dendroaspis polylepis*) or slightly more (Hodgson & Davidson, 1996; Petras et al., 2016). This speed is far slower than the fastest human sprinting at maximum 45–50 km/h. The unique serpentine locomotion of snakes, coupled with their concealing traits, rapid vanishing upon encounter, and often streamlined body coloration and patterning, elicit fear and panic (ophidiophobia), leading to overestimation of their actual speed.

Myth 10: "Some Venomous Snakes are Blind and Aggressive"

The haphazard and fierce strike-behavior of some snakes (e.g., Carpet viper *Echis ocellatus*) when provoked or cornered may create an impression of 'blind striking.' Snakes are generally wary of humans and rather than resorting to uncontrolled strikes, would carefully ascertain the expediency of such an energy-demanding defensive strategy (Glaudas, 2004). When provoked, snakes often engage in defensive warning behaviors (e.g., hissing, close-mouthed mock-striking, body flailing), often misconstrued as aggressive behavior (Gibbons & Dorcas, 2002). Hence, this myth is indicative of a fear-related misconception. Snakes may bite if provoked, harassed, or handled carelessly, often when attempts are being made to kill them (Prior & Weatherhead, 1994). This portrays a defensive rather than a perceived aggressive behavior (Spawls & Branch, 1995). The night vision-adapted small eyes and elliptical pupils of vipers appear closed during the day, creating the impression of blindness. Naturally blind subterranean burrowing snakes (e.g., Typhlopidae and Leptotyphlopidae) are actually small, non-venomous, and non-aggressive.

Myth 11: "Death Will Inevitably Occur if Snake Venom Is Spat into the Nose of a Victim"

Snake envenomation is only effective within the tissues or blood. Venom contact with intact body parts, skin, or oral cavity is thus harmless (Westhoff et al., 2010). Venom sprayed into the eyes may cause sudden and severe pain followed by corneal destruction and blindness (Chu et al., 2010). Oral exposure or absorption of venom through skin rupture, including clinical venom sucking from wounds, may also be damaging (Senthilkumaran et al., 2011). Venom is volatile, and if inhaled, can cause sensitization or even fatal allergic reactions (Prescott & Potter, 2005). The fear-related misconception that venom spat into the nose is fatal may have originated from the fact that venom sprayed into the eyes may cause blindness, given that the nasal opening is also a direct entry point into the human body.

Myth 12: "Urine from a Victim Can Cure Eye Damage from Venom-spitting Snakes"

Venom spat into the eyes of victims by cobras (Westhoff et al., 2010) from distances of 2–3 m (Berthé et al., 2013) may cause blindness in the absence of water or similar liquid to wash the eyes (Chu et al., 2010). Since urine contains high amounts of water, the locals, armed with this knowledge, may have introduced this myth as an encouragement of victims to act promptly after venom is spat into the eyes, before seeking medical attention.

Myth 13: "Some Snakes are Dangerous to Pick up Even When Dead"

Death-feigning ('thanatosis') is a defensive strategy adopted by some snakes under threat (Gregory, 2008). Venomous snakes have been known to bite and envenom victims even when appearing dead (Gehlbach, 1970), probably due to reflex action or last-resort bites (Berger, 2007). The belief that live offspring emerge from a dead, gravid snake by biting through the mother's skin may relate to misinterpreted observations of live young emerging from the cloaca of ovoviviparous vipers. This myth may have arisen as a caution for people to refrain from picking up death-feigning snakes. The common practice of burning killed snakes (notably vipers), a tendency rooted in ophidiophobia, may serve as a precautionary measure to prevent death-feigning snakes or born-alive offspring from inflicting fatal bites.

Myth 14: "Puff Adders Bury Themselves in Sand to Heal after Giving Birth to Live Young"

Puff adders bury themselves in sand as a form of camouflage or to ambush prey, and they give birth to live young through their cloacal opening (Haagner, 1990). The origin of this myth remains uncertain, but is probably a misinterpretation of observations that young snakes are born alive through the cloacal opening, possibly due to a lack of knowledge about ovoviviparity in snakes. Similar to Myth 13, the source of this myth is most likely driven by an irrational fear (ophidiophobia) of this venomous species.

Myth 15: "Some Rapid and Swift Snakes May Turn around and Chase Their Human Pursuers"

Snakes rarely attack people unprovoked except for large constrictors during normal predatory attacks, as sometimes observed in the African python *Python sebae* (Branch & Hacke, 1980; O'Shea, 2018). Occasionally, when snakes are cornered or frightened, the only means of escape may be in the same direction as the pursuer (O'Shea, 2018). This is often misinterpreted as a counter-attack, especially if the person has a morbid fear of snakes (Marais, 2014). However, some snakes, such as the black mamba in eastern and southern Africa, are known to be fearlessly aggressive and often attack repeatedly when cornered or provoked (Hodgson & Davidson, 1996).

Myth 16: "To Avoid Dying, Snakes Never Return to a Previous Skin-shedding Location"

Skin shedding in snakes is periodic and growth-rate specific with skins shed wholly or in pieces (Marais, 2014). Snakes may occasionally be found lying dead next to their shed skins. This observation may have been misinterpreted to suggest that death occurs when snakes revisit a previous skin-shedding location. The fact that snakes are rarely observed in the actual process of skin shedding may have mystified this process and spawned this myth.

Myth 17: "Pythons Break the Bones of Their Victims before Swallowing Them"

To avoid self-injury and prey escaping, constricting snakes need to subdue and quickly immobilize vigorously struggling prey (Saviola & Bealor, 2007). The prey is suffocated by coiling and squeezing around its chest to cause asphyxiation and cardiac arrest (Douglas, 1995). Additionally, spinal dislocation and extensive ruptures in cranial blood vessels may occur due to the excessively high blood pressure attributed to the immense constriction (Penning et al., 2015). Although not the main purpose of constriction, bone or spine crushing of relatively small prey may occasionally occur due to the constantly strong force applied (Douglas, 1995; Penning et al., 2015). Given that snakes have relatively small heads and mouths, there is general doubt that pythons can swallow large and bulky prey relative to their size without crushing their bones (Douglas, 1995). The myth of bone-crushing pythons is a sign of fear-related exaggeration.

Myth 18: "Pythons Swallow Their Prey Legs First"

With their recurved teeth, pythons swallow prey whole usually in a fast and easy head-first process, thereby reducing prey-handling time and the risk of predator attack (Saviola & Bealor, 2007). Sometimes, particularly inexperienced juveniles may attempt to swallow prey legs-first (Cabral et al., 2017), an abnormality mostly associated with small prey (Braz & Marques, 2016). Pythons are rarely observed during the initial swallowing phases, so the normal, faster practice of head-first swallowing has probably made the rare and prolonged occasions of legs-first swallowing more commonly observed, thus creating a misconception that the head of the prey protrudes from the snake's mouth until digestion is complete. Due

to the seemingly small heads and mouths of snakes, people generally doubt that they can swallow large and big-headed prey (Douglas, 1995).

Myth 19: "Pythons Have to Smear Their Prey with Saliva before Swallowing Them"

Pythons lubricate their prey with enzyme-laden saliva during swallowing to facilitate digestion (O'Malley, 2017). During the initial phases of swallowing, pythons may regurgitate the prey when disturbed, leaving the disgorged prey smeared with saliva and stomach mucus (Marais, 2014). The prey is actually smeared with saliva during the swallowing process, not before it, as erroneously believed by some people.

Myth 20: "Pythons are Killed Faster When Their Head to Tail Breathing Cycle Reaches the Tail"

Snakes, including pythons, usually have one non-vestigial very long lung to fit into their narrow cylindrical bodies. The lung ventilation cycle of expansion and contraction of the ribs with breathing occurs in two stages, consisting of a brief air-flow, and a longer pause, which can last for several minutes in a motionless snake (Zug & Ernst, 2015). In large and long pythons with only one extremely elongated lung, breathing movements manifest as a rise and fall of the lungs running along the body. Lung ventilation is, therefore, perceived as head-tail back-and-forth air movements with the notion that a long snake becomes unconscious when the breath is at tail-end (i.e., the head would be without air). Such a snake is misconceived to be unaware of events around it, thus less dangerous and easier to kill; a notion signifying fear of large pythons.

Snake Myths and Perceptions in Relation to Conservation in Ghana and Africa

We presented data reflecting a relatively large population segment in northern Ghana, albeit more than 10 years ago, so these results may not reflect the current situation. Initially, our primary focus was on snake ecology and epidemiology, as published in Musah et al. (2019). In retrospect, however, with a growing interest in anthro-zoological aspects of snake conservation and fear of snakes, we realized the potential usefulness of our myth data for improved understanding of theoretical and educational approaches to snake conservation. The snakebite epidemiological situation in northern Ghana, and the country as a whole, has not changed for the better since our study. Recent evidence indicates an even worsened situation, as shown by newspaper articles (Musah et al., 2019) and peer-reviewed publications (e.g., Steinhorst et al. 2021; Ameade et al., 2021). Our data, therefore, remain relevant, both in a general conservation context and also by persistently reflecting a current, rather uncontrolled epidemiological situation in the whole of the West African savanna region (Onyishi et al., 2021).

Our list of snake myths reflects the characteristic superstitious beliefs prevalent among the people of northern Ghana and elsewhere in Africa (Hambly, 1931; Smith, 2006) where narratives often abound in religion, legends, and sorcery (Attuquayefio, 2004; Wojnowski, 2009, 2010). We showed that the majority of the 20 snake myths are scientifically unsubstantiated and mostly rooted in ophidiophobia, a trend also recently identified in northern Nigeria (Onyishi et al., 2021). Our findings were similar to studies in resource-starved rural

communities with poor infrastructure and low socio-economic status of Africa, where snake mystification and superstition related to ophidiophobia and illiteracy are key underlying factors for the negative socio-cultural implications of snakebites (Attuquayefio, 2004; Onyishi et al., 2021; Smith, 2006), but also the indiscriminate persecution and killing of snakes (Tropp, 2003; Wojnowski, 2010).

The high prevalence of ophidiophobia underlying the snake myths from northern Ghana may be consistent with the notion that the inhabitants, through natural selection and their proximity to snakes, have evolved a predisposition to fear snakes as a means of survival (Isbell, 2006). Myths originating from fear of snakes may thus have a reciprocal effect by bioculturally maintaining such aversive emotions against snakes among the populace, irrespective of the current population demography (Onyishi et al., 2021). In Ghana, people tend to overreact in panic when encountering a snake, harmful or not. There is often screaming, fleeing, and attempts to kill the snake on sight. Myth generation and maintenance can, therefore, be viewed as being responses to innate ophidiophobic traits (Isbell, 2006) and/or bioculturally founded extra preparedness (Seligman, 1971) and conditioning (Rachman, 1977) toward snakes. This is borne out of frequent snake encounters and snakebites, leading to fear-related misconceptions and exaggerations about snakes (Onyishi et al., 2021). People being fearful and apprehensive of snakes engender knowledge bias, misconceptions, and thus myths about snakes. As myths are generated by innate ophidiophobia, bioculturally they also serve to maintain the fear of snakes. We propose that myths and ophidiophobia portray a reciprocal relationship, which promote negative misconceptions and aversions toward snakes in general.

We found that even though aversion toward snakes and ophidiophobia are widespread across age, gender, and educational background, older men were the most, and women the least, knowledgeable about snake myths. We suggest that the low level of knowledge about snake myths among females in northern Ghana could be partly related to the higher prevalence of ophidiophobia in females than males, irrespective of age (Rakison, 2009). This may result in low levels of interest in snakes by females and consequently limited awareness about snakes. Women and children in northern Ghana are less exposed to snakes during their daily activities, compared to the more actively-farming men. The higher exposure to snakes as a fear object might induce higher extinction of ophidiophobia in males (Fredrikson et al., 1997). Moreover, snakebite victims in northern Ghana are more often men (Musah et al., 2019), probably because they often hunt and trap snakes for bushmeat and other uses, especially during farming activities. The reciprocal predator-prey relationship in an evolutionary context provides men in West African savanna areas with relatively more polarized, ambivalent emotions toward snakes, involving fear, fascination, respect, and wonder (Headland & Greene, 2011).

Even though snake myths create undue fear of snakes and result in their persecution, we propose that the folkloristic diversity they represent also exhibits a rich cultural interest in snakes and their existence (Hambly, 1931; Sax, 2001; Stanley, 2008). Rich folklore, combined with community-based educational programs and integrated with conservation actions (Boafo et al., 2016; C. Hughes, 2013), could address issues concerning aversive snake myths and their related misconceptions (Smith, 2006; Wojnowski, 2009, 2010). Such measures would aim to replace the disgust, fear, and wanton persecution of snakes with more rational, environmentally-friendly, and science-based perceptions and awareness about ecologically important

snakes. Utilizing the diverse interest in snakes among the local people serves a good foundation for incorporating the science and reality of the natural history and behavioral ecology of snakes into community-participatory educational and awareness programs (Appiah-Opoku, 2007; C. Hughes, 2013). Such efforts should principally target basic/primary schools and other public forums and institutions harboring public information dissemination activities, such as district and municipal assemblies, community centers, libraries, and even healthcare facilities (De Groot & Zwaal, 2007; Fernández-Llamazares & Cabeza, 2018). However, as our data also show, these initiatives should likewise embrace the older and less educated men. In a predominantly patriarchal society where male elders traditionally constitute family headships, this segment should be a major focus of conservation education action that intermixes age groups and bridges the gap between myths and realities about the true nature of snakes. Combining respect for snakes found within rich serpent folklore (Sax, 2001) with rational knowledge about snake biology would create a basis for reducing the inappropriate mystification, irrational fear, indiscriminate persecution and killing of snakes, and other human behaviors that are counterproductive for snake conservation (Jacobs, 2009).

Conclusion

Most snake myths in northern Ghana are largely misconceptions without any substantial scientific basis. The perceptions that these myths represent are often unsustainable for wildlife-friendly human behavior, thus compromising snake conservation efforts. Holistic approaches integrating ethnozoological research with traditional and scientific knowledge should aim to demystify snakes, replacing negativism and fear with more rational science-based mind-sets toward understanding the true nature and behavior of these creatures. Such efforts may reduce the indiscriminate persecution and killing of snakes, and also secure the diverse folklore that surrounds this important zoological asset in Africa. Future studies should aim at investigating ophidiophobia prevalence across population segments in Ghana, including the biocultural and psychological origin of myth generation, in relation to awareness and attitudes toward snakes.

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