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UNDERSTANDING THE SNAKE MITE AND CURRENT THERAPIES FOR ITS CONTROL

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Abstract: *Ophionyssus natricis* (Parasitiformes: Macronyssidae) is a mesostigmatid mite which commonly parasitizes captive snakes. The mites feed on the host's blood by lacerating the soft skin between scales with their chelicerae. Heavy infestations are common in captive specimens and have been shown to result in severe anemia, dehydration, and death. Additionally, the mites have been shown to transmit several bacterial, protozoal, and filariid pathogens. While well recognized as a significant pest in captive snake collections, the snake mite has been difficult to control. The inability to control *O. natricis* is related to its complex life cycle, which includes both blood feeding and non-feeding stages. In order to develop a proper treatment regimen for *O. natricis,* it is critical to understand the natural history of the organism. This paper will describe the life cycle and ethology of *O. natricis* and summarize current therapies utilized in controlling and attempting to eradicate this pest.

Key words: Ophionyssus, ectoparasites, snake mite, herpetoculture

INTRODUCTION

Ophionyssus natricis (Parasitiformes, Macronyssidae) is a common blood feeding, mesostigmatid mite which parasitizes snakes. The life cycle is similar to other macronyssid and dermanyssid mites and involves egg, larva, protonymph, deutonymph, and adult stages[7] with one molt between each immature stage. The entire life cycle can be completed in 7-16 days at room temperature. The adult and protonymph stages feed on host blood by lacerating the soft skin between scales with their chelicerae. Heavy infestations have been shown to result in severe and sometimes fatal anemia[2]. While a blood meal is required for molting and maturation (protonymphs) and egg production (adult females), unfed mites can survive for prolonged periods of time under favorable environmental conditions. Elimination of mites from infested captive snakes can be extremely difficult. Despite the availability and use of numerous acaricidal compounds, severe infestations involving multiple host species are common, and the mite has remained a serious problem in captive reptile husbandry and management. The difficulty in successful treatment of infested animals is probably due, in part, to the lack of understanding of the mite's complex life cycle and behavior. While the life history of *O. natricis* has been thoroughly studied[5], this information has not been sufficiently disseminated among herpetoculturists and veterinarians. Many articles on snake mites in trade magazines and proceedings present the life cycle of *O. natricis* inaccurately, and thus further handicap the reader's ability to design an appropriate treatment regime for an already difficult problem. The intention of this article is to describe the general morphology and behavior of each stage, the clinical significance in captive reptile husbandry and management, and current therapies employed in the treatment of snake mites. The information on mite biology is largely a summary of the excellent study conducted by Camin[5] combined with observations made in working with experimentally infested snakes. Readers desiring more detail are referred to Camin's published monograph.

CLINICAL SIGNIFICANCE OF MITE INFESTATION

Snakes heavily infested with mites can develop severe and sometimes fatal anemia[2]. Mite feeding is irritating to the host and causes multifocal to focally extensive edema and erythema most notably in the gular and periocular regions of the head. Histopathologic evaluation of feeding sites demonstrates the dermal tissue surrounding the embedded mouthparts become densely infiltrated with heterophils, lymphocytes, and plasma cells with multifocal perivascular aggregates of lymphocytes and plasma cells in the adjacent dermis. Within crotalinae (pit vipers), mite infestations have been associated with loreal pit inflammation and impaction. Mite-infested snakes will frequently take refuge in water. Monitoring snake behavior and close examination of the bottom and the water surface of water bowls are useful mite surveillance techniques.

In addition to producing severe anemia and dehydration, *O. natricis* has also been implicated in the transmission of several bacterial, protozoal, and filariid pathogens[8,9,12]. Transmission of several clinically significant viral diseases including ophidian paramyxovirus and boid inclusion body disease[16] is suspected, but not yet proven. The biological relationship between the pathogen and potential vector and the mode transmission in each case is either unknown or poorly characterized. In an arthropod that feeds multiple times as an adult and once as a protonymph, mechanical, regurgatative feeding, transtadial, and/or transovarian transmission are all possible. Sexual transmission has been demonstrated with some tick borne viruses and could potentially occur in mites. Accidental ingestion of mites by the host must also be considered.

LIFE CYCLE AND BIOLOGY

Adults

Adult males and females are sexually dimorphic, active, fast crawling stages. Both sexes have well developed chelicerae and will actively feed on host blood. In an unfed state, both sexes are small and, when present in low to moderate numbers, can be easily overlooked on casual inspection of animals and/or cages.

Unfed adult males are ovoid to carrot-shaped and average 500 µm in length and 200-250 µm in width with a posteriorly tapered body[5]. The first and last pairs of legs (pairs I & IV) are approximately 50 µm longer than the two central pairs (pairs II & III). Microscopically, the dorsal and ventral aspects of the body are covered with a series of scleritized plates and have a hairy appearance attributable to numerous setae. When fully engorged, males are posteriorly ovoid, yellow to dark red or black in color and are slightly wider (300-350 µm) than unfed males[5]. The variation in color is dependent upon the density of ingested erythrocytes and the degree of blood-meal digestion, Fed and unfed males are frequently found riding on the dorsum of unfed adult or immature females (as fed protonymphs or deutonymphs) . Pairing is apparently stimulated by the size of the unfed mature or fed immature female because males will not attempt to copulate with engorged females or other males[5]. A given male will copulate with several females before and after engorgment[5]. Under favorable conditions, the life span of the adult males is similar to the adult female (i.e., up to 40 days) with or without feeding[5].

Unfed adult females are ovoid in shaped and average 600 µm in length and 300-400 µm in width with a slightly tapered to rounded body shape. Leg pairs I and IV are approximately 100 µm longer than pairs II and III. Microscopically, the dorsal and ventral aspects of the body are similar to the male, being covered by several scleritized plates and numerous setae thereby giving the mite an overall hairy appearance. Fully engorged females are posteriorly globose, and are dark red or black in color and frequently measure over 1300 µm in length. Unfed females are very active mites and will crawl around the cage rapidly in search of a host and immediately climb onto the body and crawl under scales when contacting a snake. Adult females are voracious feeders and can increase their body weight up by 1500% (0.05 mg unfed to 0.75 mg when replete) on host blood[5]. Fully engorged females tend to crawl upward in search of dark moist concealed places where they become akinetic and oviposition begins. Each blood meal will result in the production of approximately 20 eggs which are laid over a 5-20 day period depending on the environmental temperature[5]. Adult females will feed and reproduce 2-3 times at 1-2 intervals and have a life-span of up to 40 days under favorable conditions. A given female is therefore capable of producing a life-time total of up to 80 eggs[5]. Viable egg production is not contingent upon successful mating. Fertilized eggs develop into females, whereas males are produced parthogenetically from unfertilized eggs[5]. While blood meal ingestion is required for egg production, it has no influence on longevity[5].

Egg

The eggs of *O. natricis* are off-white to tan, ovoid structures which darken at one pole, but do not change in size as development ensues[5]. The eggs are visible to the unaided eye and measure about 300-400 µm in length and 200-300 µm in width. Unfertilized eggs are somewhat smaller than fertilized eggs[5]. Mated females have been shown to lay both fertilized and unfertilized eggs[5]. The eggs are developed to the blastula or early gastrula stage at the time of oviposition. The rate of development is temperature dependent and doubles with each five degree increase between 20°C and 30°C. At 25°C, the interval between oviposition and hatching is 40-56 hours[5]. The fully developed larvae merges from the posterior aspect of the egg by pushing the shell forward with its legs and pappi. Dessication resulting in ineffective hatching and larval escape from the shell is a major cause of egg mortality. Most eggs hatch into larva at relative humidities of 85% and greater[5].

Larva

The larval stage is characterized as a small, white, fragile, non-feeding, six-legged mite which measures approximately 400 μm in length and 250 μm in width. The integument is poorly scleritized and bears numerous papillae which cause the surface to have a cobble stone appearance when examined microscopically. The developing fourth leg of the later nymphal and adult stages can frequently be observed as a crescent shaped structure under the lateral integument posterior to leg III, The larval stage is very sensitive to dessication and frequently remains in the region where it hatched until it matures and molts into a protonymph. With an ambient temperature of 25-30°C, maturation and molting to protonymphs requires 18-24 hours[5]. Dessication resulting in ineffective molting is a major cause of larval mortality. Effective molting requires a relative humidity of at least 75%[5].

Protonymph

The unfed protonymph is a very active, aggressive, blood-feeding mite which is similar to the larva in overall size. The body is posteriorly tapered and there are four pairs of legs and well developed chelicerae. The dorsal and ventral surfaces are partially covered with scleritized plates and moderate numbers of setae. Leg I is slightly shorter than leg IV and legs II and III are about 40 μm shorter than legs I and IV. The posterior three pairs of legs are used for locomotion. The anterior legs bear sensory receptors in the tarsal segments and are constantly waved in front of the body in an antenna-like manner. Because of this, protonymphs may be confused with larvae on casual observation. Protonymphs will feed within 24 hours of molting and actively crawl around the cage in search of a host. Aggregates of unfed protonymphs can be found on objects within the cage. Any disturbance of the mites will result in them swarming onto the disturbing object which is usually the snake. Upon contacting a host, protonymphs quickly crawl under scales, insert their mouthparts, and will remain attached to one spot until fully engorged. The duration of feeding is largely dependent on ambient temperature. As with other physiologic processes, the rate of engorgment is temperature dependent and typically requires 3-7 days of feeding at 25°C[5]. The body of the fully engorged protonymph is ovoid in shape and is approximately twice as long as it is wide. Engorged protonymphs destined to become females are approximately 150 μm longer than those to become males. Engorged protonymphs destined to become males average 530 by 275 μm whereas those destined to become females, average 686 by 360 μm. Pairing of immature males and females frequently occurs with fed protonymphs. While a full blood meal is required for maturation and molting to deutonymphs, protonymphs have been shown to be capable of enduring long periods of starvation (19-31 days) under optimum conditions, Molting requires 12-48 hours after engorgment with the precise rate being dependent on the ambient temperature. Approximately 10-20% of the nymphs will become entrapped in the old skin and die, even at optimum temperatures and relative humidities.

Deutonymph

The deutonymph is the second non-feeding stage in the life cycle of *O. natricis*. The bodies of the deutonymphs destined to become males and females are approximately the same size of engorged protonymphs or unfed adults of the two sexes and are typically dark red to black in color. The dorsal and ventral integument lacks the scleritized plates found on protonymphs and adults and has a striated texture. The density of setae is markedly reduced in comparison to protonymphs and adults. The chelicera are soft and degenerate in comparison to those observed on blood-feeding stages. The legs are somewhat longer than those of the protonymph with pair II being the shortest of the four pairs. The deutonymph stage is of relatively short duration, lasting only about 24-26 hours at 25°C. As with other stages, the rate of maturation to adult is temperature dependent and increases with increases in ambient temperature up to a critical maximum of 40°C at which development ceases. The deutonymph is an active mite and is frequently found on cage ornaments, debris, and within the cage, but seldom on the snake. Deutonymphs are frequently paired with the smaller, prospective male riding on the dorsum of the female. As with the previous immature stages, ineffective molting is a major cause of mortality. Approximately 10% of the deutonymphs become trapped in the old skin or retain the molted skin on the limbs in a ball-and-chain fashion and eventually die, even with optimum environmental conditions.

Feeding

Protonymphs and adults feed over a prolonged period (3-8 days for protonyrnphs and 5-8 days for adults) while attached to the soft skin between scales. While feeding, both stages remain concealed under a scale until nearly replete when the posterior region of the body can be seen protruding from under the scale[5]. Mites which infest the soft tissue around the eyes or under chin scales as protonymphs will sometimes remain in these locations for life[5]. On the host's body, *O. natricis* seems to preferentially colonize the ventrolateral aspect of the body, namely scale rows one and two. Fully engorged mites tend to wander over the surface of the body and are frequently observed on the dorsolateral body before dropping from the host. The mouthparts of ticks and some blood-feeding mites consist of a pair of chelicerae which flank a central hypostome. The distal ends of the chelicerae are blade-like and function in lacerating host tissue using breaststroke-like and forward thrusting motions while the central hypostome is inserted into the newly created wound and serves as the point of attachment. Small blood vessels are mechanically lacerated and/or digested by salivary components and the parasite feeds from a pool of blood that forms around the embedded mouth parts. Blood is taken in through the feeding channels located between the chelicerae and hypostome by capillary action through the activity of a pharyngeal pump. This mode of feeding, termed telmophagy, is quite different from solenophagy, which is employed by mosquitoes and other insects which penetrate and feed directly from an intact blood vessel. While the precise mode of feeding may seem trivial, it can have direct bearing on the capacity to pick up and transmit pathogens. It should be noted, while attached mites tend to remain at the original feeding site if undisturbed, their hypostome lacks the numerous tooth-like denticles and/or attachment cement possessed by ticks. Therefore, they are susceptible to comparatively easy mechanical detachment. Detached incompletely fed mites will rapidly re-attach and resume feeding when given an opportunity[5]. These anatomical and behavioral characteristics must be given important consideration when elucidating the potential of *O. natricis* to serve as a mechanical vector for blood-borne pathogens. The kinetics of blood meal intake and its relationship to salivary gland physiology have not been studied in *O. natricis*, although the description provided by Camin[5] suggests that rapid engorgment occurs in the later aspect of the feeding period as it does in ixodid ticks.

Histologic examination of detached mites demonstrates well developed salivary glands and a midgut of *O. natricis* that is anatomically similar to that described in ticks. In both *O. natricis* and the ticks, the midgut is a sac-like structure with numerous diverticula. The mucosa is lined by simple cuboidal epithelium, composed of highly phagocytic cells. Blood meal digestion in ticks has been shown to be intracellular. Within this group of arthropods, the ingested blood is phagocytized by the epithelium, digested intracellularly, and the useful constituents released into the hemolymph from the basal aspect of the lining cells. The phagocytic midgut epithelial cells accumulate intracytoplasmic hematin in the process and are sloughed into the lumen when filled. The morphology of the midgut in *O. natricis* suggests that host blood is digested by a similar process.

BEHAVIOR

The activity of *O. natricis* is highly dependent on “hard-wired” responses to sensory inputs. Temperature, relative humidity (RH), odor, gravity, contact, and light all influence the behavior of *O. natricis*.

Temperature

O. natricis tends to congregate in areas with an ambient temperature of 20-23°C[5]. This reaction to temperature is a result of a combination of ortho-kinetic and klino-kinetic responses. The ortho-kinesis, or rate of locomotion, is directly related to temperature, with higher rates of movement at higher temperatures. Klino-kinesis, or rate of turning, gradually increase as temperatures either fall below 20°C or rise above 23°C. Movement within the 20-23°C range is comparatively straight. A mite leaving the 20-23°C, say to either 19°C or 24°C, immediately begins to turn and, as a result, is usually brought back into the 20-23°C range[5].

Most stages of mite become akinetic below 10°C, however, fed and unfed adult females become akinetic at 2°C and 6°C respectively. The larval stage is akinetic at all temperatures, including those approaching the thermal death point. The thermal death point, that temperature at which the mite dies after a five second exposure, is 50-55°C for all stages[5].

Relative Humidity

In addition to the negative effect of low humidity on hatching (0% hatch at RH < 50%) and molting (<50% success at RH <50%), humidity also effects the behavior of the mite. Humidity has little ortho-kinetic effect, however a strong klino-kinetic effect does exist. In all stages, except the larvae which are akinetic, the rate of turning increases as the mite goes away from 95% RH. Thus, a mite leaving 95% RH has a tendency to return to that zone. At 95% RH, the mites become relatively akinetic with time[5]. Despite their preference for high relative humidity, *O. natricis* is quite vulnerable to drowning in a water droplet.

Odor

O. natricis possess chemosensory setae at the tips of tarsi I which enable them to differentiate odors in the environment[5]. Not surprisingly, snake mite are attracted to a live snake, but not to a dead snake or a live mouse. Furthermore, *O. natricis* shows a preference for snake blood over snake skin, snake feces, and coagulated snake blood. However, they do not discriminate snake blood from frog blood[5]. *O. natricis* will feed on non-snake species, including humans, but whether they can complete their life cycle on alternate hosts is unknown. A large infestation of *O. natricis,* including multiple stages, has been noted in a captive southern alligator lizard (*Elgaria multicarinatus)* housed adjacent to an infested common boa (*Boa constrictor)*(DeNardo and Wozniak, unpublished data).

Gravity

All stages are generally negatively geotactic, preferring to move upward. When confronted with an obstacle, they usually proceed to climb it, rather than circumvent it. When reaching the top of an object, they often become akinetic until disturbed[5].

Contact

O. natricis is suspected to have sensory setae on the edges of the anterior dorsal shield[5]. It appears that in order to become akinetic and feed, the anterior aspect of the dorsum must be at least partially covered. If snake skin is stretched to remove the overlap of scale on skin, mites in an attached container will starve. The tendency to become akinetic upon dorsum contact also promotes clumping of mites located off of a host.

Light

O. natricis possesses photoreceptors in the pretarsi of the anterior leg, and possess a very pronounced klino-kinetic response to light. Mites move in a comparatively straight pathway in darkness, and a very winding pathway in light. Therefore, they turn abruptly when leaving a shaded area, resulting in them returning to the darker area. Ortho-kinesis is unaffected by light intensity[5]. The degree of negative phototaxis in the adult female is variable, with the variation directly correlated with the degree of engorgment. Fully engorged females tend to take a straight path directly away from a light source compared to unfed females whose avoidance route is very convoluted[5].

Relative importance of environmental stimuli

Akinesis, or lack of movement, is greatest in darkness and 95% RH. However, intense light appears to be the strongest stimuli. While not as strong as intense light, gravity provides a stimulus greater than that of diffuse light or heat.

TREATMENT

Significance of life history and behavior

Much of the proceeding information may seem excessive, but it is critical to understand the life history of the snake mite in order to devise the best treatment to attempt *O. natricis* eradication for any given situation. Several components of the mite life history are extremely critical.

Foremost is the fact that all stages spend at least part of the time OFF the host, with the egg, larval, and deutonymph stages usually spending their entire time off host and never blood-feeding. Therefore, any treatment plan must consider mites that are not only on the host, but also in the host's environment. Usually, this requires direct treatment of both the host and surrounding environment. Since mites show a great preference for darkness and have a tendency to go up, it is critical to include all crevices and corners, especially those at the top of the cage, in the treatment plan.

While all stages, including the egg, are visual to the unaided eye, many of the immature stages are not as obvious as the engorged female. A single visual observation is not sufficient to declare a snake or cage mite-free.

The longevity of the protonymph and adult (up to 45 days with or without a blood meal) dictates that the treatment plan can not be short-term. Many current plans employ two treatments of short acting compounds at 10-14 day intervals. Such a plan is destined for failure. Recurrence of mite infestations post-treatment are common and probably attributable to the failure to kill all mites. Most commonly, recurrence is not noted for nearly 2 months post-treatment. Given the reproductive potential of the mite, this relatively long time to recurrence is understandable.

As an example, consider the time frame of the following. A single egg survives a treatment of a mite infested snake. Having probably originated from a fertilized female, this egg would contain an embryo destined to be a female. The egg would become an adult mite in approximately two weeks, at which time she would lay up to 20 unfertilized eggs, each destined to become a males. These new eggs would mature in approximately two weeks with one of these males copulating with the original female. She then would repeat her laying of nearly 20 eggs, but this time the eggs would be primarily fertilized ones and, therefore destined to become mostly females. These F2 mites would be difficult to detect because they would be few in number and relatively small for much of their development. It would take two weeks more for these F2 mites to become mature and lay their own eggs. It is probably not until these F3 mites mature (another two weeks) that the infestation might be detected. While only an example, it took eight weeks for this "recurrence" to be detected; much like what is typical.

The biology of the snake mite can also help predict "at risk" animals. While snakes are the only known animals that can harbor a population of *O. natricis*, it is the experience of the authors that some lizards (e.g., *Elgaria*) are also vulnerable. Due to the need for mites to have their dorsum in contact with an object for feeding, smooth-scaled species (e.g., geckos) are at minimal risk of mite infestation. Contrarily, species that require a humid surroundings (e.g., many tropical boids) are at high risk of mite infestation, since it is at high relative humidity that the snake mite thrives best.

Water

Snakes with an *O. natricis* infestation frequently submerge themselves in their water bowl. This behavior is oftentimes the reason that the infestation is detected by the care giver. Mites are highly sensitive to drowning, and, thus, soaking in water provides some relief to the host. A common, and most basic, treatment for snake mites is to soak the host in water. Like the host's self-imposed baths, this practice will help reduce the number of mites on the infested animal. However, the kill on the host is never 100% and the host's environment, which is equally infested, is not addressed. Therefore, this practice rarely, if ever, brings the infestation down to non-detectable levels, let alone achieves eradication.

While not sufficient when used alone, water can be used as an adjunct treatment. Since all stages of mites are susceptible to both drowning and high temperatures (e.g., death occurs within five seconds at 55°C), soaking cages and cage furniture in hot water between uses can be an effective and non-toxic treatment for mite control. Animals which are severely compromised (e.g., dehydrated, anemic) due to heavy mite infestation can have the parasite load significantly reduced with daily soaks in water until the general heath of the snake is adequate to permit chemical treatment.

Desiccants

Due to their small size, mites are susceptible to contact with any of the numerous desiccant silica gel powders available (e.g., Dri -Die). However, since mites routinely travel up cage walls, rather than residing within the bedding, contact of the mite with the powder is not assured. Small reptiles, especially neonates, are themselves vulnerable to desiccants since they are in contact with the powder for extended periods. Additionally, crystalline silica is carcinogenic, and, therefore, these products should probably best be avoided.

Dichlorvos

Probably the most commonly employed treatment for snake mites is the use of dichlorvos, an organophosphate, in the form of a "no-pest" strip. Traditionally, a 1-3cm piece of the dichlorvos-imbedded strip is placed in the affected cage for a day. This treatment is repeated every 10-14 days for 1-2 additional treatments. More recently, with the reformulation of the dichlorvos content of the strips, it appears that the strip needs to be placed in the host's cage for an extended period (2-3 days) during each treatment.

Dichlorvos treatment has the advantage of treating both the host and the environment. As a result, total eradication of *O. natricis* from a captive snake colony has been achieved by the sole use of dichlorvos (Staub, pers. comm). More typically, dichlorvos effectively reduces mite infestation, often to non-detectable levels, but true eradication is not achieved, leading to resurgence of the infestation.

Dichlorvos can be toxic to both the host species and human care giver. However, these strips are frequently used, with only few reports of clinical toxicosis. Dichlorvos is hepatotoxic, and therefore chronic use may lead to non-acute illness. To reduce the potential of toxicity to both the reptiles and care giver, gloves should be worn when handling dichlorvos and dichlorvos containing strips should be kept in sealed containers when not in use. A relatively acute fatal toxicity with associated skin lesions has been anecdotally noted on several occasions in Brazilian rainbow boas (*Epicrates cenchria)* after exposure to dichlorvos (Blody, pers. comm.; Price, pers. comm; Staub, pers. comm.).

Pyrethrins and pyrethroids

Pyrethrins and pyrethroids are another commonly employed treatment for *O. natricis.* Pyrethrins are natural products from pyrethrum flowers (*Chrysanthemum* spp.), while pyrethroids are synthetic products similar in structure. While usually deemed safe and somewhat effective at controlling and sometimes eradicating mites, toxicity, including fatalities, have been reported[4,10,11]. The occasional occurrence of toxicity may be a result of the variation in available products, their use, the species being treated, and the housing conditions. There exists a wide variety of pyrethrins and pyrethroids, and the potency, toxicity, and half-life of these products is variable. In general, pyrethroids are more potent and have a longer half-life than pyrethrins. In addition, the carrier material in the commercial products varies, with some being water based and others oil-based. As a result of product variation, treatment regimens which are safe and effective with one product may be ineffective or lethal with another product.

In addition to the variation existing in the products, there is variation in the way in which these products are used. Pyrethrins and pyrethroids can be applied by either bathing in a shampoo or spraying the animal and it's environment. The latter benefits by including the environment in the treatment, but also leaves excessive residual product. Animals bathed in pyrethrins or pyrethroids are often rinsed with water shortly after exposure (5-10 minutes). Rinsing is aided (especially for oil-based products) by adding a mild soap (e.g., Ivory) to the rinse water. Regardless, of application method, repeat treatments are needed, but the suggested frequency and duration are variable.

What may be the largest contributor to pyrethrin or pyrethroid toxicity is the way in which the recipient snake is housed. Snakes housed in cages with low ventilation (e.g., drawer cage units) appear to be more prone to toxicity. Toxicities are best treated with supportive care, with the removal of residual insecticide and the provision of clean air probably the most important. Prevention of toxicity is best accomplished by using pyrethrin and pyrethroid products diligently. Once a treatment protocol is well-established, one should be aware of any changes in the product being used, the application protocol, the species being treated, and the housing conditions. A change in any of these parameters warrants close observation of the treated individuals.

Ivermectin

The activity of ivermectin is a result of its stimulatory action on γ-aminobutyric acid (GABA), an inhibitory neurotransmitter. It can be used to treat *O. natricis* by applying it via intramuscular injection at a dose of 0.2mg/kg[15] or as a spray (5mg ivermectin:1 liter water)[1]. When injected or sprayed, the duration of treatment varies with some claims of a single treatment being effective (spray[1]) and other claims for the need for repeated treatments (injectable weekly for 3 weeks[15], spray q4-5 days for 3 weeks, Klingenberg, pers. comm.). The primary advantage of ivermectin is that it acts systemically and has a relatively long biological half-life (7 days in cattle[6]), and thus remains at therapeutic levels in the blood stream for extended periods. The absorption of ivermectin through reptile skin has not been determined, so its effect when applied via spray may only be a local one.

While treating the environment is usually beneficial, it may be unnecessary when using ivermectin due to the long half-life of the drug. Any mites off the host, will eventually need to take a blood meal, at which time they will be exposed to the ivermectin. Anecdotal observations by the senior author also suggests that there may be host species variation in the effectiveness of ivermectin in eradicating mites, with treatment more effective in colubrid snakes compared to boid snakes. Reports of toxicity and death using ivermectin in squamates exist[3], however these toxicities are predominantly in lizards.

Insect growth regulators

More recently, insect growth regulators (e.g., lufenuron) have gained attention in the treatment of ectoparasites. These products are primarily inhibitors of chitin synthesis, and thus impede egg hatching and molting. While not yet significantly utilized on reptiles, these products share with ivermectin the advantage of being systemic and having long biological half-lives (60 days for lufenuron in dogs and cats[13]). However, since these products do not provide immediate kill of the mite, they are probably not suitable for the treatment of clinical cases of mite infestation, but more appropriate for attempts to eradicate mites from a colony.

CONCLUSION

The snake mite, *Ophionyssus natricis,* is a significant ectoparasite of captive snake. It can cause irritation and clinical disease as well as act as a vector for other disease agents. *O. natricis* infestations are common and not readily eradicated. Current treatments encompass numerous products delivered in multiple fashions, oftentimes two or more treatments are combined[14]. The existence of the diversity of treatments lay credence to the inefficacy of any one treatment. Much of the failure in treatment is a result of a poor understanding of the complex life cycle and behavior of the snake mite. Combining a better understanding of the life history of *O. natricis* with controlled studies of promising therapeutic agents will hopefully lead to more effective treatments for eradication, thus minimizing one of the more prevalent problems facing captive snakes.

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