Notes

Risk of Snake Entanglement Is Affected by Installation Method of Erosion Control Blankets

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Abstract

At the conclusion of road construction projects, an erosion control product (e.g., blankets, spray mulch) is installed to reduce soil loss and promote plant growth. Wildlife, such as snakes (suborder Serpentes), are prone to entanglement in erosion control blankets (ECBs) that contain polypropylene mesh with fused apertures. Previous reports have noted that the occurrences of entanglements are not uniform in their distribution across an ECB, but primarily occur where the edge of the mesh is exposed. We conducted an experiment to determine if modification to the installation methods of ECBs affects the likelihood of snake entanglement. We conducted entanglement trials to compare the likelihood of snake entanglement between two treatments: 1) exposed ECB edge (i.e., perimeter) and 2) buried ECB edge. Snakes were less likely to attempt to pass through the mesh on the buried edge treatment and all entanglements occurred on the exposed edge treatment. These results provide support that modification to the installation methods reduces snake entanglement in ECBs in some settings. However, we conducted our study in an experimental setting, and it should be evaluated under natural field conditions. This research can be used to inform several parties including contractors, habitat managers, and agency decision makers on additional steps that can be taken for products that fit their application needs to minimize risks to wildlife.

Keywords: conservation; mesh; mitigation; reptile; road ecology; soil stabilization

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Introduction

Roads pose risks to wildlife through habitat fragmentation and are an additional agent of mortality because of traffic volume and affect both ecological and evolutionary processes (Andrews et al. 2015). Additional hazards to wildlife associated with roads include road construction and maintenance and resulting mitigation efforts (Jacobson and Tonjes 2015). For example, as of August 2019 in Texas, there were 6,739 active projects,

and 6,448 additional construction projects were listed to begin in the next 4 y (Texas Department of Transportation 2019). Soil erosion and water-body sedimentation are well-known problems associated with construction sites that continue to experience soil loss despite regulatory and mitigation efforts (Kaufman 2000). Roadway construction projects expose soil to weathering agents (e.g., wind and rainfall) that increase the erosion rate (Benik et al. 2003). To reduce the erosion potential of these construction projects, erosion control products (ECPs) are installed at the completion of a project (Babcock and McLaughlin 2013). The Texas Department of Transportation (TxDOT) mandates that ECPs must be placed on unpacked soil in the surrounding landscape to prevent soil loss and promote plant growth after a road maintenance project (Texas Department of Transportation 2018). All ECPs available for use after a project are compiled in TxDOT's approved product list (APL), which contains products ranging from mesh blankets to sprays and mulches (e.g., hydromulch). To be placed on the APL, products must pass two performance standards: 1) how well the product protects the seedbed of an embankment or drainage channel from the loss of sediment during simulated rainfall or channel flow events and 2) how well the product promotes the establishment of warm-season perennial vegetation (Texas Department of Transportation 2018). However, for an ECP to be listed on the TxDOT APL, there are currently no criteria that consider their risk to wildlife.

Erosion control blankets (ECBs) pose a threat of entanglement to wildlife that often leads to their mortality because of heat exposure, desiccation, increased vulnerability to predation, or deep lacerations caused by twisting in the mesh (Stuart et al. 2001; Walley et al. 2005; Ebert et al. 2019). Previous studies found that ECBs with certain characteristics (e.g., fused apertures, mesh composed of polypropylene) increase the probability of wildlife entanglement (Stuart et al. 2001; Ebert et al. 2019). For example, ECBs with fixed apertures do not expand to allow snakes (suborder Serpentes) to pass through, whereas woven mesh allows the aperture to expand, permitting snakes to move through the mesh netting and avoid entanglement (Kapfer and Paloski 2011; Ebert et al. 2019). Furthermore, some ECBs contain plastic material that is slow to degrade (e.g., 1–3 y) and may pose a long-term threat to wildlife.

In their review, Ebert et al. (2019) found that reptiles were most frequently entangled in mesh products used for wildlife exclusion, followed by ECBs. Of the reptile taxa entangled, snakes were most vulnerable to entanglement, as they comprised 89.1% of the 175 reports (Ebert et al. 2019; 9.1% were lizards and 1.7% were turtles). Snakes possess several traits that contribute to their frequent entanglement in ECBs. Many snakes are active foragers with large home ranges and thus have an increased likelihood of encountering ECBs installed on the landscape (Mushinsky 1987; Carfagno and Weatherhead 2008). Male snakes, for example, often engage in mate searching behavior and traverse long distances in search of females (Bonnet et al. 1999). At high latitudes, annual emergence from hibernacula during summer months often coincides with construction projects (Gregory 2011), which may further increase their risk of entanglement. Additionally, roads retain heat and are often used by snakes for thermoregulation (Sullivan 1981), thus increasing the potential encounter rates of snakes with ECBs on the landscape since ECBs are often associated with roads. Ebert et al. (2019) found that when a snake does encounter and attempt to pass through an ECB, its risk of entanglement increases with increasing body circumference (e.g., adults, gravid females, larger-bodied species). However, this correlation is dependent upon the characteristics of the ECB (e.g., size of mesh apertures).

Multilayered polypropylene mesh blankets with fused apertures are used on TxDOT construction sites (personal observation) and pose the highest threat to snakes because of their susceptibility to entanglement (Ebert et al. 2019). As of 2018, the majority of ECPs on the TxDOT APL contain harmful attributes, with at least 86% of the products having mesh, at least 71% containing polypropylene material, and at least 55% having fused apertures (C. M. Schalk, Stephen F. Austin State University, unpublished data). In a series of entanglement experiments, Ebert et al. (2019) noted that snakes frequently became entangled at the edge of the ECB where they first encountered the mesh layers. This suggests that even though ECBs can cover large expanses of the landscape, the perimeter or edge of the ECB may be the most dangerous to snakes. Therefore, the impacts of the exposed perimeter can be mitigated by burying the edge of the ECB in soil to reduce their encounter rate. Although snakes will still encounter the ECBs with the same frequency, the snakes are more likely to move on top and over the ECB instead of between the mesh layers, which increases their risk of entanglement. However, no previous studies have investigated the effect of installation methods on the likelihood of wildlife entanglement in ECBs. Since the majority of ECPs on the APL contain attributes associated with snake entanglement, we conducted an experiment to determine if a modified installation technique (i.e., burying the edge of the mesh blanket) would be an effective method to mitigate snake entanglement. We hypothesized that burying the edge of an ECB would reduce the number of attempts to pass through the mesh, thereby reducing entanglements.

Methods

We collected snakes used in this study from the Stephen F. Austin Experimental Forest in Nacogdoches County, Texas and South Boggy Slough Conservation Area in Trinity County, Texas. We caught snakes in box traps (Burgdorf et al. 2005), pitfall traps, minnow traps, trashcan traps (Luhring et al. 2016), or by hand (McDiarmid et al. 2012). We used 91 snakes from 12 species in our experimental trials that we conducted from 21 May 2019 to 22 July 2019 (Table 1; Data S1, *Supplemental Material*). We released all snakes at their capture sites after use in the entanglement experiment.

Table 1. Sample size per snake (suborder Serpentes) species that we used in the entanglement trials, along with the number of snakes per species that became entangled in or attempted to pass through the erosion control blanket during the trials. We wild-caught all snakes in box traps, pitfall traps, minnow traps, trashcan traps, or by hand at the Stephen F. Austin Experimental Forest in Nacogdoches County, Texas or South Boggy Slough Conservation Area in Trinity County, Texas between 21 May 2019 and 22 July 2019.

		Buried edges			Exposed edges		
Species	**Number of individual snakes**	**Number of individual snakes attempting**	**Total number of attempts**	**Number of snakes entangled**	**Number of snakes attempting**	**Total number of attempts**	**Number of snakes entangled**
Eastern racer *Coluber constrictor*	20	3	7	0	16	33	6
Coachwhip *Coluber flagellum*	7	1	1	0	6	10	3
Western mud snake *Farancia abacura*	1	0	0	0	0	0	0
Eastern hognose snake *Heterodon platirhinos*	3	0	0	0	3	4	2
Prairie kingsnake *Lampropeltis calligaster*	1	0	0	0	1	1	0
Speckled kingsnake *Lampropeltis holbrooki*	1	0	0	0	1	2	0
Glossy swampsnake *Liodytes rigida*	1	1	4	0	1	1	0
Plain-bellied water snake *Nerodia erythrogaster*	9	0	0	0	7	9	3
Broad-banded water snake *Nerodia fasciata*	2	0	0	0	2	2	1
Diamond-backed water snake *Nerodia rhombifer*	2	0	0	0	2	5	0
Western ratsnake *Pantherophis obsoletus*	33	2	2	0	20	31	3
Western ribbonsnake *Thamnophis proximus*	11	1	1	0	10	30	0
Total	91	8	15	0	69	128	18

Our protocol for the entanglement trials followed Ebert et al. (2019). The experimental arena consisted of two sections (2 × 3.35 m) of BIOMAC SC ECB (Maccaferri Inc, Rockville, MD) at each end of an aluminum-sided hardware cloth arena (7.62 × 2 m), with a patch (1 × 2 m) of bare soil between the two sections of ECB where we introduced the snake at the start of each trial. We selected the BIOMAC SC as the ECB for the entanglement trials because it possesses several attributes correlated with snake entanglement (Ebert et al. 2019). The characteristics of BIOMAC SC include multiple layers (2), polypropylene netting, fused intersections, small apertures (top, 161.29 mm^2; bottom layer, 362.9 mm^2), photodegradable, longevity of 730 d, and a matrix consisting of 70% straw and 30% coconut fiber. In the first treatment, we installed the ECB on the basis of the manufacturer guidelines by placing metal stakes every meter along the edge and left the edge exposed (i.e., not buried; Figure 1A). In the second treatment, we installed the ECB by placing metal stakes every meter along the edge and buried 10 cm of the edge (i.e., perimeter of ECB) with soil (Figure 1B). We

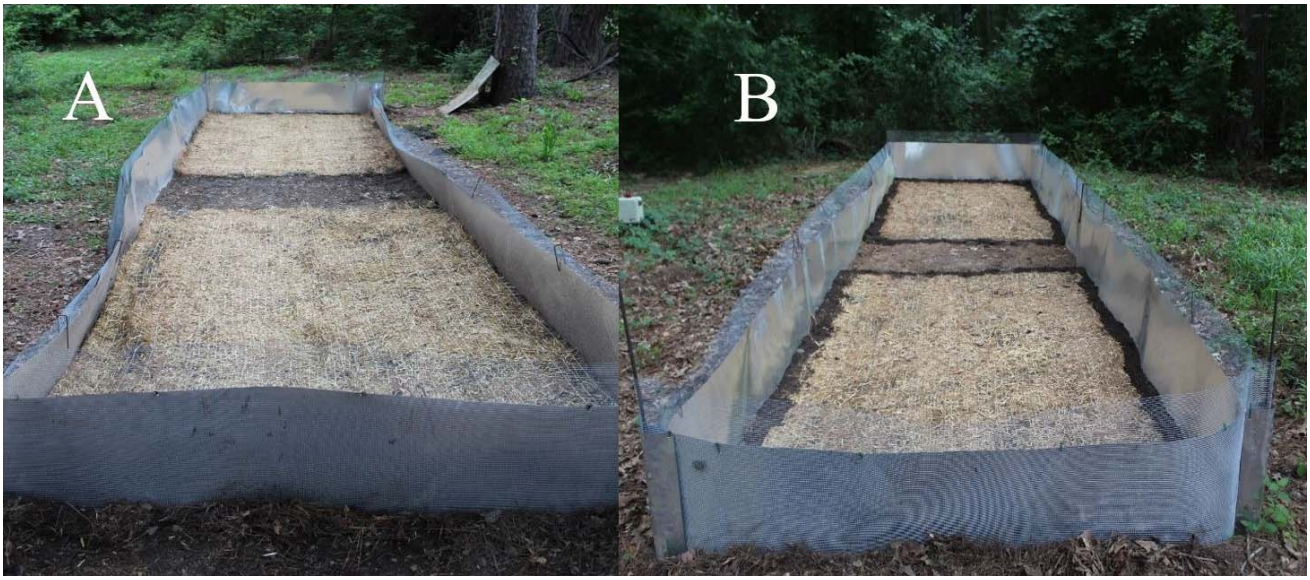

Figure 1. Two experimental arenas (7.62 × 2 m) composed of hardware cloth and aluminum siding. We placed a 3.35 × 2 m section of BIOMAC SC erosion-control blanket (ECB) at each end of each arena with a patch of exposed soil (1 × 2 m) where the snake (suborder Serpentes) was introduced. A = exposed edge treatment with the ECB staked down only and B = buried edge treatment with the ECB staked down and buried along the edges with soil. We conducted entanglement trials at the Stephen F. Austin Experimental Forest in Nacogdoches County, Texas between 21 May 2019 and 22 July 2019.

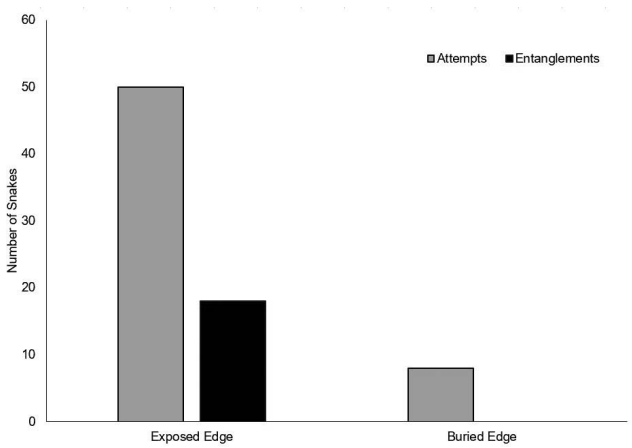

Figure 2. Number of snakes (suborder Serpentes) attempting to pass through the erosion control blanket (ECB) and entangled snakes on exposed and buried ECB treatments. An entanglement was defined as when a snake becomes caught in the ECB mesh. An attempt was defined as when a snake passed its head or body through the mesh netting but did not become entangled. No snakes became entangled on the buried edge treatment. We conducted entanglement trials at the Stephen F. Austin Experimental Forest in Nacogdoches County, Texas between 21 May 2019 and 22 July 2019.

alternated the treatments between the arenas every other day.

We tested each snake once in each treatment with a rest period (minimum 10 min) between each trial. Trials lasted 3 min or until the snake became entangled, upon which we ended the trial and removed the snake. If a snake did not come into contact with the ECB after 1 min, we tapped it on the tail with a snake hook at 1-min intervals until movement occurred. We gave snakes that did not come in contact with the ECB at the end of the trial a 10-min rest period and retested it in the same treatment ($n = 2$). For each trial, we recorded the number of attempts to pass through the mesh, the number of successful passes through the mesh, if the snake became entangled, and the location of entanglement on the ECB (Data S1). We defined an attempt as a snake passing its head through the mesh netting and pulling it back out or completely passing its entire body through the mesh without becoming entangled.

Because we were limited by the number of snakes that could be used in the entanglement experiment, we used each snake in both treatments (i.e., both buried and exposed edge treatments). We arranged trials in a two-treatment crossover design, but we assumed no carryover or period effects (Ebert et al. 2019). Therefore, we used McNemar's test to assess consistency in responses across our treatments since our experimental trials utilized the repeated use of subjects.

Results

A greater proportion of snakes attempted to pass through the ECB in the exposed edge treatment ($n = 51$ snakes attempted; 56%) than in the buried edge treatment ($n = 8$ snakes attempted; 9%; $S = 61$, $df = 1$, $P < 0.0001$; Figure 2; Table 1). Eight snakes attempted to pass through the ECB on both the exposed edge and buried edge treatments and 22 snakes did not attempt to pass through the ECB in either treatment. The total number of attempts was greater on the exposed edge treatment ($n = 128$ attempts) compared with the buried edge treatment ($n = 15$ attempts; Table 1). All snake entanglements ($n = 18$) occurred when the ECB edge was exposed (Figure 2) and 17 of those entanglements occurred on the edge of the ECB. No snakes were entangled on the buried edge treatment. Of the entangled snakes, five were entangled in the top mesh netting layer (aperture size = 1.90 × 1.90 cm), eight were entangled in the bottom mesh netting layer (aperture size = 1.27 × 1.27 cm), and five became entangled in both layers. The probability that a snake would attempt to pass through the mesh was not affected by the order of treatments.

Discussion

The majority of the ECPs on TxDOT's APL possess attributes associated with wildlife entanglement such as polypropylene mesh, fused apertures, and small aperture size (0–500 mm^2; C. M. Schalk, Stephen F. Austin State University, unpublished data). Even though there are meshless alternatives for every slope and soil type on TxDOT's APL, these meshless products cannot be used under certain circumstances (e.g., high rainfall, floodplains, stream channels; Kapfer and Paloski 2011). Although use of these products may not be avoidable, certain measures may be taken to decrease the likelihood of entanglement. We found that modification of the installation methods resulted in snakes making fewer attempts to pass through the mesh when the ECB edge was buried, leading to no entanglements in our trials. All entanglements occurred on the exposed edge treatment as snakes first encountered and contacted the exposed mesh of the ECB's edge.

Entanglement in an ECB is a stepwise process that starts with coming into contact with the exposed mesh, then attempting to pass through an aperture of the netting, then finally becoming caught in an inelastic aperture (Stuart 2001; Kapfer and Paloski 2011; Ebert et al. 2019). Inhibiting any part of this entanglement process would contribute to the reduction of snake mortality from ECBs. Snakes have evolved sensory mechanisms, foraging behaviors, and antipredatory defenses that allow them to rely on and respond to ecological cues to survive and reproduce successfully (Lillywhite 2014). For example, when a predation threat looms overhead, snakes seek temporary refuges to reduce exposure to predators (Bowers et al. 1993). However, as humans alter the environment, the cues that wildlife rely on to make decisions that are tied to adaptive outcomes are no longer reliable (Schlaepfer et al. 2002). ECBs are novel features in the environment to snakes and other wildlife and may represent an ecological trap (Schlaepfer et al. 2002). By seeking refuge under sources of cover, it reduces exposure and

detection by predators, but these anthropogenically modified landscapes increase engagement in risky behavior as snakes are more likely to attempt to pass through an ECB. When a snake first encounters the exposed ECB edge, they have an increased probability to pass through the ECB, but when the edge is buried, their only option is to move on top of the ECB. Therefore, snakes no longer engage in the risky behavior that leads to an entanglement. Modifying the installation method by burying the edge of the ECB inhibits snakes from contacting the exposed layers of plastic netting, which reduces the number of attempts to pass through the mesh and reduces the number of entanglements.

All but one entanglement occurred on the edge of the mesh blanket, supporting the previous observations from Kapfer and Paloski (2011) and Ebert et al. (2019) that entanglement is not homogenously distributed across the ECB. Although ECBs are deployed over large areas and not regularly checked or surveyed after installation, the entire area of the mesh blanket may not pose significant risks to wildlife. The perimeter of the blanket where the layers of plastic netting are usually frayed and raised off the ground may be spatial concentrations (i.e., hot spots) for entanglement risk. Because the exposed ECB perimeter is the primary cause of entanglement, burying the edge of existing ECB products may be less burdensome as the ECB area that needs to be modified is reduced.

Although the results from our experiment show that burying the edge of the ECB was effective at minimizing snake entanglement, these results may not be consistent under natural conditions. In our experimental trials, ECBs were installed on level terrain. When the edges of the ECBs were buried, we created a feature with only one surface (the top of the mesh) that was readily accessible to snakes. When the ECB edges were not buried, the snakes tended to encounter a three-dimensional structure. Even with a buried edge, uneven terrain in natural field conditions will likely create additional entanglement opportunities as the snakes may encounter wrinkles or folds in the ECBs. Also, it is not known how long the ECB edge may remain buried when it is exposed to rainfall or other weathering agents under natural field conditions. Further, many ECBs are degradable and break down over time (Theisen 1992; Khanna 2007). During the degradation process, new edges may form, causing the locations for entanglement to shift within the ECBs. For example, BIOMAC SC takes up to 24 mo to photodegrade, which may result in a mosaic of hot and cold spots for entanglement across space and time. Burying the edge also increases installation time, subsequently increasing costs, and may dissuade contractors from utilizing this method.

Many states or provinces have implemented regulations to mitigate the negative impacts of roads on wildlife (e.g., road mortality) such as the creation or installation of wildlife corridors and tunnels (Patrick et al. 2010; Bain et al. 2017). Our results support the hypothesis that additional steps of burying the edge of an ECB can minimize the negative impacts of ECBs on snakes. If meshless or woven ECBs are not available (Kapfer and Paloski 2011; Ebert et al. 2019), our modified methods of ECB installation will allow contractors to reduce entanglement risk to snakes and other wildlife. Although the modified installation methods may require additional costs, the mitigatory efforts are well justified, especially when the ECBs are deployed in ranges of rare, threatened, or endangered snake populations. These results provide agencies, contractors, restoration companies, and nonprofit organizations alternatives to minimize the threats certain ECBs pose to wildlife while still meeting the objectives of reducing soil loss and promoting vegetative growth.

Supplemental Material

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Data S1. All data for the analyses supporting the results of this paper. The data file (.xlsx) includes the 1) individual snake morphological data and 2) results of the entanglement trials for each snake. We conducted entanglement trials at the Stephen F. Austin Experimental Forest in Nacogdoches County, Texas between 21 May 2019 and 22 July 2019.

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