Herpetological Conservation and Biology 6(1):1–9.
Submitted: 21 January 2011; Accepted: 15 March 2011.

ON THE THREAT TO SNAKES OF MESH DEPLOYED FOR EROSION CONTROL AND WILDLIFE EXCLUSION

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***Abstract.*—Concerns about snake mortality due to entanglement in plastic mesh deployed for erosion control and horticultural pest exclusion have been previously raised. However, little new information has been published on the subject, although the threat may not have abated. Herein, we provide evidence that snake entanglement in such materials continues to occur by reviewing new case examples from Wisconsin. We also summarize information about a variety of materials used for erosion control and horticultural pest-exclusion and give our perspectives on the potential threats (if any) these pose to snakes. This document is meant, in part, to serve as a reference for natural resource regulators, academics, and environmental consultants when making suggestions on the application of such materials. We hope this will help reduce the likelihood of snake entanglement. Further research focused on testing the level of threat posed by mesh entanglement and the best methods for application of mesh in a variety of settings is warranted.**

Key Words.—entanglement; erosion control; erosion fences; mesh, risk.

INTRODUCTION

Entanglement of reptiles in anthropogenic objects is not a new phenomenon (examples reviewed by Dean et al. 2005). In snakes, numerous accounts of entanglement in a variety of materials have been reported including wire (Campbell 1950), beer cans (Groves and Groves 1972; Herrington 1985; Iverson 2010), and other materials (Fauth and Welter 1994; Bonnie et al. 2004; Vann et al. 2005; Ortega and Zaidan 2009). With the exception of Ortega and Zaidan (2009), these reports mostly describe individual observations or a limited number of observations. Some past reports have specifically raised concerns about snake mortality due to entanglement in plastic mesh deployed for soil erosion control and horticultural pest exclusion (Stuart et al. 2001; Barton and Kinkead 2005; Walley et al. 2005a,b). Over five years after the majority of the reports related to plastic mesh entanglement were published, we review recent case examples of related phenomena from Wisconsin, USA.

To provide wildlife managers, environmental consultants, and regulatory agencies with an up-to-date document on this subject, herein we summarize the categories of materials that are used in a variety of situations. We give perspectives on these materials as they relate to snake entanglement. We cannot make definitive recommendations due to a lack of available information and research on snake entanglement in mesh or netting. Yet, we believe it is important to have baseline information and perspectives available in the scientific literature for reference, particularly because plastic mesh continues to result in snake mortality. We hope this document will provide a conceptual framework for future research and as an aid to decision-making in current projects.

SUMMARY OF EROSION CONTROL AND WILDLIFE EXCLUSION PRODUCTS AND APPLICATIONS

***Erosion control products*—**The diversity of materials and applications associated with erosion control products may confuse the novice (Lexau 2009). Knowledge of basic industry descriptions and applications can help wildlife biologists make effective recommendations to land managers, developers, or government agencies seeking advice on projects in areas where snakes may be present. Therefore, we summarize the current product terminology discussed in Lexau (2009) and by the Erosion Control and Technology Council (ECTC; Erosion Control and Technology Council. 2008. Available from http://www.ectc.org [Accessed 20 January 2011]). The ECTC is an organization that provides information for erosion control product manufacturers; as well as, to those who work for entities that regularly use erosion control materials. ECTC indicates that their goal is to be the industry authority in standards development, review of methods for installation, and testing of erosion control products. Although ECTC has no regulatory authority and their suggestions are non-binding, they have created standard industry terminology. We have also sought the advice of experts in the field of erosion control material application and efficacy for advice.

The most straight-forward type of material to employ for erosion control purposes is a simple layer of loose

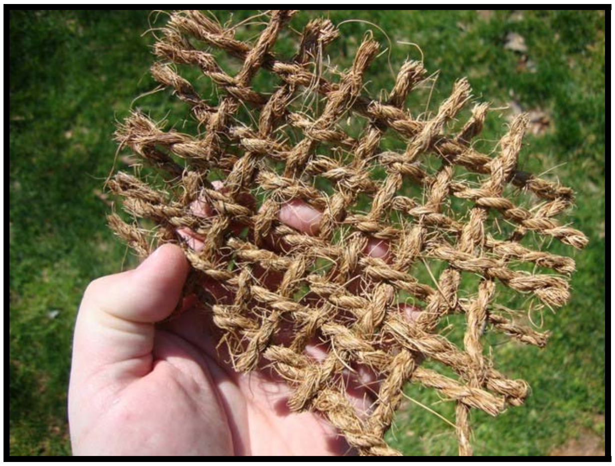

FIGURE 1. Example of an open textile weave (OWT) erosion control product. (Photograph of a manufacturer's sample square by Josh Kapfer)

FIGURE 2. Example of an erosion control blanket (ECB) product that incorporates biodegradable woodstraw and two layers of a synthetic polymer mesh (note elongated apertures). (Photograph of a manufacturer's sample square by Josh Kapfer)

organic matter (wood mulch, wheatstraw, woodstraw, coconut/coir, etc.) with no associated weave or mesh. Although this method is often employed and may be suitable for small-scale application (i.e., the flower or vegetable beds associated with a private residential property), it has extremely limited application in other situations. It is not effective for many large scale projects with significant ground disturbance, projects on substantial slopes, or in areas subject to frequent inundation or flowing water. Longer lasting and stable erosion control materials are usually required in commercial and industrial situations. Sometimes a Mulch-control Netting (MCN) is applied to help stabilize a loose mulch layer. MCNs are unrolled over loose organic layers and seeds, then stapled or staked into place. They are usually designed of woven natural or geosynthetic fibers that are reported to be degradable.

Rolled Erosion Control Products (RECPs) are classified as either temporary (e.g., open weave textile, OWT; erosion control blankets, ECBs; Mulch-control Net, MCN; see above) or permanent (e.g., turf reinforcement mats, TRMs). OWTs are typically made of organic or synthetic strands that are woven into a matrix (Fig. 1). ECBs are commonly employed to control erosion and usually constructed of a continuous fiber matrix comprised of layers that may be structurally bound. The ECB matrix may include layers of organic materials, polypropylene fibers or a polymer mesh with apertures that range from less than 5 mm^2 to over 25 mm^2 (Fig. 2). Examples of organic materials employed range from straw and coconut (coir) to wood fiber and jute or burlap. The mesh layers are often stitched to the matrix with a polypropylene thread or biodegradable fiber such as cotton. OWTs and ECBs are used for a wide variety of purposes. They are employed to provide fast protection to exposed soil that will quickly become stabilized with vegetation. Occasionally, OWTs are used as an underlay to reinforce sod. In addition to control of erosion, these products are often designed to hold moisture and stabilize seeds or young plants. They may be applied in urban and rural areas for residential, commercial, and industrial projects. They are also used along roadside embankments, ditches, drainage ways, stream banks, and riparian areas. Although some OWTs and ECBs are designed to degrade over time, the speed of degradation depends on the materials used in their manufacture (synthetic vs. organic materials). As a result, their life spans can range from several weeks to several years.

TRMs are often applied in situations where vegetation is not able to grow to a point that controls erosion without additional stabilization (Fig. 3). They may also be applied to inundated areas, locations that experience flooding, or areas subject to high velocity flowing water. Typical situations where they are employed include stream banks, stormwater channels, and slopes subject to heavy stormwater run-off. TRMs are usually permanent, and often incorporate synthetic fiber, plastic filaments, or wire mesh, with a range of aperture sizes (< 5 mm^2 to > 25 mm^2). This mesh is frequently bonded at filament intersections, but may also be discontinuous or loosely held together by weave, stitch, or glue. Mesh that is not bonded at the intersections may not be permitted in some states under certain applications (Wisconsin Department of Transportation. 2010. Erosion control Product Acceptability Lists (PAL). Prepared by WisDOT ECSW Committee (Peter J. Kemp, Chair). Prepared for the WisDOT Engineers and Project Development Staff and Consultants. Available from http://www.dot.wisconsin.gov/business/engrserv/docs/pal.pdf [Accessed 21

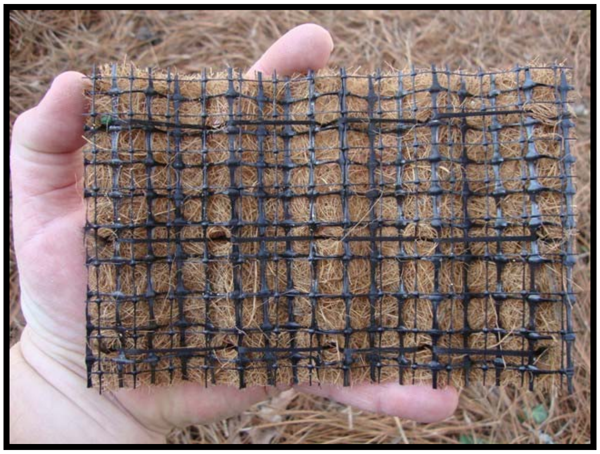

FIGURE 3. Example of a turf reinforcement mat (TRM) product that incorporates several synthetic layers bonded together (note mesh includes square, not elongated, apertures). Although the product in this example includes a degradable layer (coir), numerous products with no degradable layers exist. (Photograph taken from a manufacturer's sample square by Josh Kapfer)

FIGURE 4. Example of a hydraulically applied erosion control product (HECP) being applied in-situ. (Photographed by Marc S. Theisen)

January 2011]). This non-degradable mesh may (or may not) be used in conjunction with layers of degradable material. All of these layers are then bound into a matrix that is secured to the ground permanently. The type of materials incorporated into the TRM matrix can be chosen to meet the specific needs of the project. TRMs are expected to last for long periods of time and give vegetation the support necessary to establish and thrive under conditions with potentially high volume and velocity run-off.

Hydraulically applied erosion control products (HECPs) are relatively new in the erosion control industry (Erosion Control and Technology Council. 2008. *op. cit.*). Usually, HECPs include numerous components, such as fibers (organic and synthetic), tackifiers, absorbents, polymers, and other materials designed to stimulate plant growth. These are mixed into a slurry that is sprayed or spread on over an area in need of ground stabilization and vegetation establishment (Fig. 4). They are reported to be particularly useful along banks, slopes and even in relatively flat locations. They do not perform as well if inundated or even subject to periodic flooding, due to the buoyancy of their components. Although application of these products have become popular, according to ECTC, the cost-effectiveness or other benefits of this material is largely unknown.

Wildlife control products.**—**Plastic netting of various mesh size (often referred to as "deer fence," "snake fence," "bird netting," or "wildlife netting") is frequently employed to exclude animals considered pests, such as birds, ungulates, or snakes. These are applied in large and small-scale horticultural operations and to prohibit birds and bats from nesting within buildings. They are occasionally promoted by bird enthusiasts as a means to successfully deter snakes from entering bird houses when it is affixed to poles, or other structures, to which bird houses are attached (Walley et al. 2005a). Plastic mesh has also been recommended as a type of fencing material that will keep snakes from entering homeowner lawns and gardens (e.g., Pierce 2003), and is sold by some manufacturers specifically to entangle snakes for this purpose (Fig. 5).

RECENT ACCOUNTS OF SNAKE ENTANGLEMENT

The following are recent accounts of snakes entangled in RECPs or netting used to exclude horticultural pests

FIGURE 5. Bullsnake (*Pituophis catenifer sayi*) entangled in netting deployed to deter birds from crops in a private horticultural setting (Dane County, Wisconsin, USA). (Photographed by Bruce Ellarson)

in Wisconsin. These accounts were relayed to us from a variety of sources. In some cases, the observations were made by co-workers of RAP. In other instances, the observations were made by private citizens and sent to the authors. All observations were accompanied by photographs for verification, and were sent to the authors because of our current employment by a state regulatory agency, or our knowledge of snake ecology. These accounts are case examples and do not represent every occurrence of snake entanglement in plastic mesh in Wisconsin. Given the fact that: (1) most cases likely go unreported, or unnoticed; (2) multiple species of various sizes and life-history requirements are reported herein; and (3) the accounts listed here have been reported from throughout the state, this information can give some indication of the frequency at which such mortality occurs. It can also give a general indication of the level of threat these materials pose to a wide range of species. Future studies are needed to assess what impact this mortality has on snake populations.

Bullsnake *(Pituophis catenifer sayi)*.**—**11 June 2010, Dane County, Wisconsin. An adult individual was found entangled in polypropylene mesh used to exclude birds from a strawberry bed (ca. 2.54 cm^2 mesh aperture size; Fig. 5). The snake was removed from the fence and released upon encounter. A mass of bird feathers was found within the netting near the captured snake and it is possible the snake was attempting to (or had succeeded in) prey upon birds when entangled. This species is listed as Special Concern/Protected in the state of Wisconsin (Christoffel et al. 2008).

Common Gartersnake *(Thamnophis sirtalis)*.**—**9 May 2008, Waupaca County, Wisconsin. Several adult individuals (exact numbers not reported) were found dead after becoming entangled in erosion control matting (mesh size unreported but from pictures appears to be 1.27 cm^2). The mesh was used for soil stabilization as part of a recent road and bridge construction project.

Eastern Hognose Snake *(Heterodon platyrhinos)*.**—**20 June 2010, Eau Claire County, Wisconsin. One adult individual was found dead after becoming entangled in plastic monofilament netting commercially available to exclude White-tailed Deer (*Odocoileus virginianus*) from a vegetable garden (mesh aperture size 1.92 cm^2).

Northern Watersnake *(Nerodia sipedon)*.**—**11 May 2009, Lafayette County, Wisconsin. Adult individual was found dead in erosion control matting (mesh aperture size un-reported but based on pictures was likely 1.27 cm^2). The erosion control mesh was deployed in associated with a stream and several wetlands.

Western Fox Snake *(Pantherophis vulpinus)*.**—**On 20 June 2004, 22 adult individuals were observed trapped in erosion control blankets associated with the Menominee River along the border of Marinette County, Wisconsin and Menominee County, Michigan, USA. Sixteen snakes were cut free and released from plastic mesh, while six were dead-on-arrival. Mesh aperture size was unreported but likely 1.27–1.90 cm^2.

Western Fox Snake (*Pantherophis vulpinus*).**—**8 and 9 May 2010, Wood County, Wisconsin. Three adult individuals were found entangled in polypropylene netting attached to the base of apple trees to deter wildlife. These observations made over two days and the trapped snakes were released as encountered with no reported mortality. Mesh aperture size was not reported but likely ca. 2.54 cm^2.

In the past several years, the Wisconsin Department of Natural Resources has received several anecdotal reports of Butler's Gartersnakes (*Thamnophis butleri*; a threatened species in Wisconsin) and additional Common Gartersnakes entangled in plastic erosion control matting. Unfortunately, specific information regarding dates or locations of observations was not provided for these reports. Walley et al. (2005a) summarized personal communications with Gary Casper regarding several Butler's Gartersnakes entangled in plastic erosion control mesh in Ozaukee County, Wisconsin observed in 2004. We have also received anecdotal reports of deceased snakes frequently observed in erosion control mesh from the southeastern United States (David G. Cooper, pers. comm.).

PERSPECTIVES ON MESH APPLICATION

We emphasize that we have not conducted controlled experiments on the efficacy of these products as they relate to erosion control, or snake "safety." We base our comments on: (1) product descriptions; (2) visual assessment of products within the categories discussed previously; (3) knowledge of potential product applications; (4) discussions with erosion control industry specialists; (5) knowledge of snake ecology and biology; and (6) reports of entanglement. We did visually assess in-hand examples of the products in categories mentioned. We do not endorse one product or company over another.

Erosion control products.**—**Regulations and standards for acceptable erosion control materials vary by state, by governing body, and by institution. These regulations are also likely to change over time. Therefore, it is difficult to create overly-specific, "snake-friendly" recommendations for application of erosion control materials that comply with state regulations across the

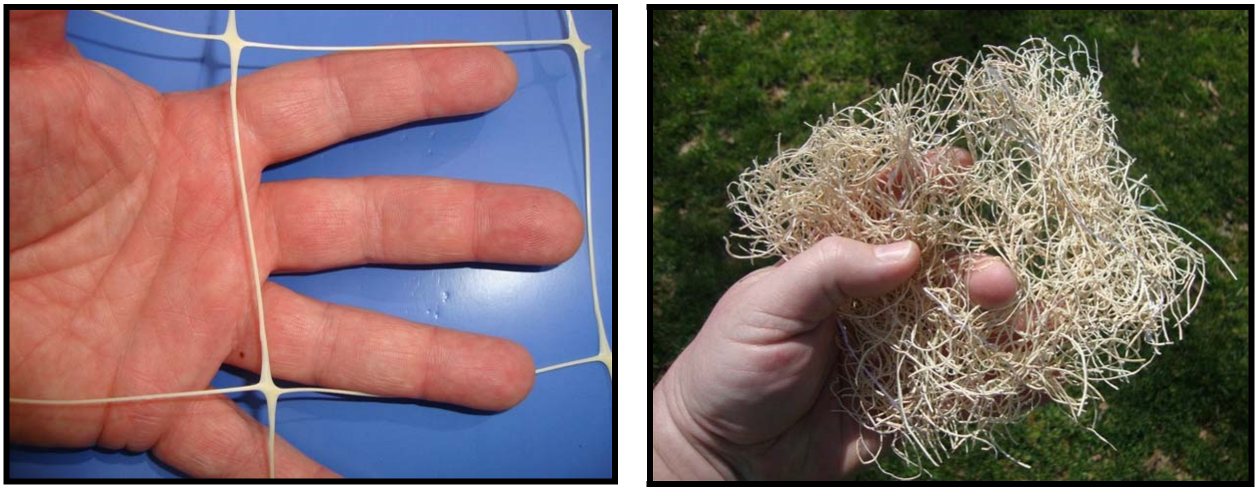

FIGURE 6. Wildlife exclusion net with large apertures that are unlikely to entangle snakes (left) and an unwoven, unbound RECP with organic fiber matrix and no associated plastic mesh (right). Compare above products to the tightly woven, open textile weave (Fig. 1), unwoven, unbound RECP with organic fiber matrix with associated plastic mesh (Fig. 2), and the smaller meshed turf reinforcement mat (Fig. 3). (Photographs taken of a manufacturer's sample square by Josh Kapfer).

country. For example, the Wisconsin Department of Transportation (WDOT; *op. cit.*) has criteria that products must meet to be considered acceptable, and it is up to the manufacturer to submit evidence that supports their acceptability. Product acceptability is based on how well they hold up to shear stress (i.e., the force that flowing water exerts on an obstacle in its path) and how well they cover a given area. These requirements are necessary for the product to effectively control erosion, but do not consider how likely they are to entangle snakes. WDOT considers an erosion control product acceptable for use in "environmentally sensitive areas" if it has biodegradable components, which includes the mesh material, and an open non-bonded mesh weave. Although it is encouraging that anecdotal information suggests this WDOT requirement for environmentally sensitive areas has effectively reduced snake mortality (Melissa Gerrits, pers. comm.), this has not been rigorously vetted.

Wisconsin has specific state regulations for application of erosion control materials (which may or may not reduce snake entanglement), but these products may not be regulated this stringently in all states. It may be necessary for wildlife biologists to make recommendations on projects in states where regulations do not exist, or are more lenient. We make the following suggestions to aid in this process. We also expect these perspectives will be improved upon with future research and as experience with products grows.

From our own observations and past reports, snake morality due to entanglement appears to be more common with products that incorporate plastic mesh with small, square apertures. For example, all of our case examples above involve mesh with small square apertures ranging from 1.27–2.54 cm^2. Of the erosion control applications discussed, it seems those least likely to entangle snakes are loose layers of organic materials, such as wheatstraw, woodstraw, wood mulch and coconut (coir), and HECPs (used alone and not in conjunction with a plastic mesh). These possess no interconnected matrices, nets, or weaves that may accidentally entangle snakes, assuming an MCN is not also applied. Should an MCN be used in concert with loose organic layers, the tightness of the weave must be considered to assess the threat of snake entanglement. Unfortunately, loose organic layers and HECPs often contain buoyant components and do not effectively control erosion in areas of frequent inundation (Peter Kemp, pers. comm.). As a result, the use of some type of RECPs is often required.

Based on product manufacturer's descriptions and visual inspections of products, we make educated assumptions about the applied efficacy of several RECPs. It appears that OWTs that incorporate a "leno" or "gauze" weave provide a reasonable option for the reduction of snake entanglement. The weave of these blankets should allow individual strands to move independently. This potentially gives snakes greater ability to pass through the weave while still maintaining product durability. Anecdotal evidence and reports from industry employees suggest that the use of such materials in place of plastic netting in sensitive areas has reduced observations of snake entanglement in Wisconsin (Melissa Gerrits, pers. comm.). We have noticed that in some products the weave of OWT strands is tight. In the products we assessed, this tight weave made it difficult for us to easily pass our fingers through the product (Fig. 6). We can imagine snakes would have equal difficulty passing through the material. Some RECP products are constructed of an unwoven and unbounded organic fiber matrix. Visual assessment revealed that this matrix produced no resistance to our fingers when we attempted to pass them through it (Fig. 6). It appears that such products are less likely to entangle snakes than a tightly woven OWT. Yet, RECPs that have no woven or bound matrix may not adequately control erosion in all situations (e.g., steep slopes, exposed to high water velocity).

Some state regulatory agencies require that erosion control products contain biodegradable components if they are applied in environmentally sensitive areas (Peter Kemp, pers. comm.). Products made solely of biodegradable materials (jute, woodstraw, coir, etc) may result in reduced snake mortality compared to products made of synthetic mesh, even if those synthetic materials are photodegradable. Care must be taken when using natural, biodegradable products (i.e., hay or straw) in erosion control to insure that the seeds of non-native or invasive plants are not accidentally introduced with the product. To help avoid this, many companies provide products that are certified as weed-free.

It should be noted that some ECBs contain layers of both organic, biodegradable materials, and plastic mesh. These products potentially pose the same risk as those made of only synthetic materials. A logical option to avoid snake entanglement may be to employ products that do not use plastic mesh or netting, particularly in areas with potential for sensitive or legally protected species. It is possible that biodegradable and photodegradable mesh still poses an entanglement hazard to snakes. Particularly if mesh aperture size is too small and snakes become entangled before the product degrades. Unfortunately, the ECTC indicates that erosion control materials without some form of netting are not sufficient for application in steep slope and high water velocity situations. In such cases, plastic mesh products with elongated apertures have been recommended, as there is some evidence to suggest they pose less of a threat to snakes (see below).

Past observations of numerous snakes entangled in plastic mesh with aperture sizes of 1 and 2 cm^2 at restoration sites in South Carolina (USA) have been reported (Barton and Kinkead 2005). They suggest employing permanent TRMs with a very small mesh size of < 0.5 cm^2 to reduce snake mortality in areas where protected species exist. Although this may be an effective means to reduce adult snake mortality, hatchlings and juveniles of many species, particularly the smaller natricine species (*Thamnophis* and *Storeria* sp.), may still be subject to accidental capture. Although most reports that we have received or encountered in the literature are of adult snakes, juvenile snakes that die in netting may be less obvious, eaten by predators, or decompose before they are noticed.

Several RECPs with plastic mesh exist that are promoted as being “wildlife-friendly.” To our knowledge, these claims have only been tested as they apply to snakes for a product called NatureZone, manufactured by Conwed Global Netting Solutions (Minneapolis, Minnesota, USA; Guangda Shi, pers. comm.; see Fig. 2 for an example of a product that includes elongated apertures). These plastic mesh products have been developed with mesh apertures that are more elongated than those of traditional plastic mesh with square apertures. This type of mesh construction has been promoted as allowing passage of snakes, and substantially reducing entanglement-related mortality.

Controlled experimental trials have been conducted on NatureZone ® (Conwed Global Netting Solutions, Minneapolis, Minnesota, USA) and other products with various aperture sizes, to determine the level of snake-entanglement risk it poses (Tony Gamble, pers. comm.; Guangda Shi, pers. comm.). The experimental animals (all adults) used in these trials were two Racers (*Coluber constrictor*), three Corn Snakes (*Pantherophis guttata*), two ratsnakes (*Pantherophis obsoleta* and *P. emoryi*), a Gophersnake (*Pituophis catenifer*) and two Common Gartersnakes (*Thamnophis sirtalis*). Snakes were housed with RECPs possessing one of four possible mesh sizes (1.27 x 1.4 cm, 0.635 cm x 3.175 cm; 2.03 cm x 4.32 cm; 7.62 cm x 10.16 cm; no more than one mesh type per trial, with exposure times of up to 165 h).

Although the results of this research have not been published in the open scientific literature, the findings shared through personal communication with Conwed employees and university researchers hired to conduct the tests indicate that mesh sizes of ca. 1.27 x 1.4 cm were most likely to result in snake entanglement. On the other hand, products such as NatureZone ® with elongated mesh apertures (0.635 cm X 3.175 cm; 2.03 cm X 4.32 cm; 7.62 cm X 10.16 cm) captured fewer snakes (Tony Gamble, pers. comm.; Guangda Shi, pers. comm.). This supports the claim that products with elongated mesh apertures reduce the likelihood of snake entanglement. However, based on our recent report of a Bullsnake becoming entangled in mesh with large apertures ca. 2.54 cm^2, it is possible that products with enlarged apertures still pose a risk to larger, heavy bodied species if the mesh is fixed at thread intersections. It will be necessary to carefully consider the application of any product comprised of a mesh with fixed thread intersections in areas with high densities of snakes, or known to possess species that are rare and/or large in diameter.

Wildlife control products.—Documented observations of mortality due to entanglement in wildlife control products are uncommon, likely because they are rarely reported. However, Stuart et al. (2001) discuss an account of several Coachwhips (*Masticophis flagellum*) entangled in mesh deployed to protect fruit trees from birds. Numerous examples can be found on internet blogs and websites of snakes trapped in plastic mesh deployed to protect bird houses. Recommendations for the use of netting to exclude horticultural pests in ways that reduce the risk of snake mortality are difficult to make. This is primarily because the use of netting in this fashion is not regulated or monitored as stringently as erosion control materials. In addition, no controlled testing has been performed on the level of threat they pose to wildlife. Some materials are also employed specifically to entangle snakes in order to protect bird nest boxes, or exclude snakes from residential properties. Although some bird-enthusiast web pages report that captured snakes were released prior to death, snakes may quickly reach lethal body temperatures if the mesh is exposed to direct sun. Plastic cones, affixed to the pole on which a nest box is attached, may also deter some snakes, but anecdotal reports of snakes gaining enough purchase to bypass these cones exist. Anecdotal examples also exist where food-grade oils (i.e., vegetable oil, olive oil, or shortening) have been successfully employed for this purpose, with better results than inverted cones. We recommend application of food-grade oils be considered carefully, as their use may attract other unwanted nest predators (i.e., Raccoons; *Procyon lotor*). As an alternative, it seems logical that application of a synthetic lubricant (such as WD-40) to poles that nest boxes are mounted on may effectively prevent snakes from gaining access to these boxes. Most lubricants have limited application in nest boxes that are not mounted on metal poles or other smooth surfaces.

Incorporation of netting with large apertures should be considered if the primary goal is to protect crops or ornamental plants from larger grazing wildlife species, such as ungulates. Even apertures as large as 8–10 cm^2 should exclude ungulates, while posing little risk to snakes (Fig. 6). If the goal is to exclude birds (either from grazing on crops or from nesting within buildings) and smaller net apertures are required, use of products with elongated apertures may prohibit birds and pose a reduce entanglement threat to snakes. Care must be taken with application of such mesh on homes and trees, as other small vertebrates like bats may still become accidentally entangled regardless of aperture size and shape. Unfortunately, plastic netting with elongated apertures is not widely available for such applications.

Conclusions

Erosion control materials are valuable in stabilizing soil and seed banks; as well as, reducing soil run-off into adjacent water-bodies. The exclusion of horticultural pests is also important for a variety of reasons, including economic purposes. Therefore, it is necessary to determine what types of materials can be employed to meet these needs, yet do not entangle snakes. It is plausible that mortality due to entanglement in such materials poses minimal or no threat to snake populations. However, this cannot be assumed and research to further assess the level of threat is warranted.

The easiest material to use in soil stabilization is a loose layer of broadcasted organic material (e.g., wood mulch, coir, etc.). It is unlikely to entangle snakes because it does not contain any type of mesh or woven layers, assuming an MCN is not also applied. It also appears that HECPs pose little to no threat of snake entanglement for the same reason. We believe that the use of loose organic layers or HECPs are sound options if one hopes to avoid snake entanglement, assuming the substances used as part of the HECP slurry (i.e., tackifiers, etc.) are not toxic. RECP products constructed of an unwoven and unbounded organic fiber matrix may also pose a reduced threat of entanglement compared to those with plastic mesh layers (Fig. 6). For example, OWTs with strands woven such that they move freely should allow passage of snakes. If the weave is too tight and strands have little mobility, a threat may still be present. Unfortunately, woven strand products without a plastic mesh may not be as effective at controlling severe soil erosion.

The traditionally employed plastic mesh with small square apertures and filaments bonded at the intersections is well known to entangle snakes. It has been suggested that RECP products made of plastic mesh with large elongated apertures may pose a reduced risk of snake entanglement. Preliminary controlled experiments on erosion control products with this design have yielded positive and encouraging results. However, the likelihood that these products will entangle snakes has not been tested with large sample sizes, or in applied situations in the field. We feel strongly that further experimentation on these products is necessary (see Suggestions for future research below).

The Erosion Control and Technology Council gives recommendations for the application of materials to reduce the impact to snakes that are mostly in-line with our perspectives (Erosion Control and Technology Council. Wildlife and Erosion Control. Available from http://www.ectc.org/resources/WildlifeAndErosionControl.pdf [Accessed 20 January 2011]). Although we agree with many of their suggestions, they indicate that plastic netting or mesh can be used if it is possible to insure that it is "fastened securely to the ground and terminal edges are trenched and/or secured properly to eliminate bridging of the underlying soil and buckles/loose edges in the netting." They suggest this reduces the chances that snakes will try to move "through the RECP netting structure and get lodged in its opening." However, this claim has yet to be confirmed through controlled experiments.

Local and state regulations for acceptable products employed to reduce soil erosion may vary. These products may also vary in their likelihood to entangle snakes. Therefore, we suggest that wildlife biologists also become familiar with their local regulations when making recommendations on projects.

Suggestions for future research.—There has been very limited rigorous research conducted on the potential impacts of erosion control and wildlife control products on snake mortality and populations. Further controlled experiments on a variety of OWTs, nettings, and mesh types with various aperture sizes are warranted. Such experiments should attain greater replication than has been possible in the past: a higher number of individual snakes, multiple species, and multiple age classes of these species per category of erosion control and wildlife control products. More concentrated effort should be placed into assessing the threat that snake entanglement poses to populations. Most of our reported observations of snake entanglement occurred serendipitously. It would be valuable to conduct surveys for snakes entangled in various erosion control and wildlife control products *in situ*. These surveys should start immediately after application of the product and continue for, at least, three to six months (or until the materials have degraded and no longer pose an entanglement threat). It would be useful to conduct these surveys on several different types of materials (mesh, OWTs, and simple organic layers) deployed in several different habitat types. Long-term *in situ* studies that incorporate large sample sizes to explore snake entanglement rates in plastic mesh with large apertures would be very useful. This is largely because plastic netting is often a requirement for suitable soil erosion control in many situations.

Research is necessary to test the ability of various wildlife control products to exclude target wildlife species without entangling snakes (e.g., ungulates feeding on ornamentals, or birds nesting in buildings). This should include (controlled and *in situ*) experiments on mesh or netting with various aperture sizes, made of various materials, and in a variety of settings.

The suggested studies would be relatively easy to design and conduct, if materials could be obtained from manufacturers for testing, or researchers were given access to conduct surveys in areas where products have been recently deployed (i.e., recent road construction or development projects). Furthermore, the results of such experiments must not be proprietary. To be accessible for those that are most likely to incorporate it in decision-making (i.e., environmental regulators, consultants and conservation biologists), the results of such research must be freely available in the open scientific literature.

Acknowledgments.—Bruce Ellarson, Fred Fetter, J. King, and Paul White (Wisconsin Department of Natural Resources); Bill Poole (Project Manager, Stantec, Inc.); Denise Tiller, Ed Rodgers, and Tom Wagner all sent information on observations of snake entanglement. Tony Gamble (University of Minnesota) commented on work conducted to test snake entanglement in certain products. Melissa Gerrits (Wisconsin Department of Transportation) helped track down information about erosion control products approved for Wisconsin. Peter Kemp (New Products Engineer, Bureau of Technical Services, Division of Transportation System Development, Wisconsin Department of Transportation) provided invaluable insight and input on the application and testing of erosion control products. Sean Syring and Guangda Shi (Conwed Global Netting Solutions; Minneapolis, Minnesota) provided information on results of product testing. Numerous companies provided free product samples and provided photographs depicting their products in-situ to be used in this manuscript. Lisie Kitchel (Wisconsin Department of Natural Resources) graciously reviewed an earlier version of this manuscript.

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Erratum fixed 5-5-2011. Figure 6 required alteration in text and picture.

JOSHUA M. KAPFER (pictured here showing undergraduate students a copperhead, *Agkistrodon contortix*, captured in a funnel trap) has been involved in field research on the ecology of amphibians and reptiles for over a decade. Josh received his B.S. (1999) and M.S. (2002) in Biology from the University of Wisconsin-La Crosse, and his Ph.D. (2007) in Ecology and Evolution at the University of Wisconsin-Milwaukee. He has worked as a State Regulator with the Wisconsin Department of Natural Resources (Bureau of Endangered Resources) and as an Environmental Consultant with Stantec, Inc. He is broadly interested in wildlife ecology and conservation, with a particular focus on habitat selection, spatial ecology, and how these are affected by land-use patterns. Josh is currently an Assistant Professor in the Departments of Environmental Studies and Biology at Elon University (North Carolina, USA), and an Associate Researcher at the University of Wisconsin-Milwaukee Field Station, Wisconsin, USA. (Photographer unknown)

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