EXAMINING VARIABILITY ASSOCIATED WITH BULLET FRAGMENTATION AND DEPOSITION IN WHITE-TAILED DEER AND DOMESTIC SHEEP

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SUMMARY OF FINDINGS

Lead (Pb) is a toxic metal and is the primary material used in bullets to hunt white-tailed deer (*Odocoileus virginianus*). We conducted a study to examine bullet fragmentation patterns and to assess lead levels in white-tailed deer and domestic sheep (*Ovis aries*) using different types of bullets and firearms. The firearms we tested included a centerfire rifle, a shotgun, and an inline muzzleloader. For the centerfire rifle, we used lead bullets that are designed to expand rapidly upon impact and are frequently marketed by manufacturers for use while hunting mid-sized game such as white-tailed deer. We also tested lead bullets that are designed to retain a high percentage of their bullet weight as well as non-lead (Copper [Cu]) bullets. Not all data were available at the time we wrote this report, but we do summarize and speculate about data that were immediately available and also our direct observations. We caution readers not to use this report to set public policy because future findings based on final data analysis may conflict with our preliminary findings.

INTRODUCTION

Lead is a toxic, heavy metal found in the natural environment. It is also the most common metal used in ammunition for harvesting game species. Due to the known toxicological effects associated with lead, it poses a potential public safety concern for humans consuming venison from deer that were harvested using lead-based ammunition.

In terms of game harvest management, white-tailed deer are considered light, thin-skinned game and ammunition manufacturers market (recommend) bullets that are designed to expand rapidly upon penetration. Typically, bullets designed to expand rapidly are lead-based, and are designed to fragment with the intent to transfer the maximum amount of energy possible. Bullets of this type are often marketed for use while hunting mid-sized deer species (e.g., *Odocoileus* spp.), pronghorn (*Antilocapra americana*), bighorn sheep (e.g., *Ovis canadensis* spp.), and other species typically ranging from 34-136 kg (75-300 pounds). We will refer to these types of bullets as “Rapid Expansion” bullets throughout this report.

Alternatives to the Rapid Expansion bullets exist and are usually marketed as bullets that have properties that allow for a slower expansion. They typically penetrate deep into the body after striking thick skin, heavy bone, or thick muscle tissue. Bullets of this type usually include lead, but are designed not to fragment and are often marketed as retaining >90% of their weight after striking the animal. Bullets of this type are typically marketed for hunting larger animals such as elk (*Cervus canadensis*), moose (*Alces alces*) and other species weighing >226 kg (>500 pounds). It is important to point out that these bullets may be manufactured for calibers that are too small for larger game mammals (e.g., 6mm rifles), but the bullet is clearly different than the Rapid Expansion bullet because it is designed to retain a high percentage of its weight and not fragment. We will refer to these types of bullets as “Controlled Expansion” bullets throughout this report.

Some ammunition manufacturers also market bullets that are not lead-based but are designed for both mid-sized and large game mammals. These bullets are made entirely from copper or a copper-based alloy and are assumed to be a non-toxic alternative. These bullets are often marketed as: 1) “lead-free” to comply with non-toxic state regulations (e.g., California) and, 2) able to retain >95% of its weight after striking the animal, which implies that the bullet is not designed to fragment inside the animal. We will refer to these bullets as “Copper” bullets throughout this report.

The southern portion of Minnesota is a shotgun-only hunting area where the only legal ammunition for deer hunting is a shotgun slug or muzzleloader. Shotgun slugs are generally designed for mid-sized game mammals such as deer. The traditional slug is often referred to as a “Foster Slug”. This type of slug has rifling on the bullet, which purportedly makes it more effective while shooting through a smoothbore shotgun. The Foster Slug is lead-based and is the most common type of shotgun cartridge purchased for deer hunting. Ammunition manufacturers have recently begun making shotgun ammunition using Copper bullets and they are also marketed for use while hunting mid-sized game mammals.

The number of deer harvested in Minnesota during the muzzleloader season has increased exponentially over the past decade, particularly over the past 5 years. Both lead-based and Copper bullets are available for muzzleloader hunting and are marketed for use while hunting mid-sized and large game mammals.

To our knowledge, no studies have been published that examined the variability of bullet fragmentation and deposition using distinctly different categories of bullets available for centerfire rifles, shotguns, and muzzleloaders. However, Hunt et al. (2006) studied bullet fragmentation patterns in deer carcasses and offal piles using radiographs. While the study was able to confirm that metal fragments existed inside deer carcasses, the study used animals that were opportunistically made available to the researchers and only 23 deer carcasses were examined. In addition, these 23 deer were harvested using different calibers that would have had varying bullet weights, a description of the lead-based bullets used to kill 19 of the deer examined was not included (whether the bullet was a Rapid Expansion bullet or a Controlled Expansion bullet), estimated shot distances ranged from 37 to >200m (40 to >218 yards), and no deer were harvested using shotguns or muzzleloaders.

Similarly, Dobrowolska and Melosik (2008) analyzed lead concentrations in muscle tissues of wild boar (*Sus scrofa*) and red deer (*C. elaphus*) harvested by hunters in Poland. The authors concluded that muscle tissue closer to entrance/exit wound had a higher concentration of lead. However, their samples were not standardized as they were drawn opportunistically from animals harvested with different calibers and bullet types. The authors admitted that caliber and bullet type would be an important factor related to the extent of contamination, but that their study was not designed to address lead contamination levels in muscle; rather to simply point out that meat derived from game animals taken with lead-based bullets will be contaminated with lead.

Our intent was to conduct an experiment that would control for the centerfire caliber and focus on examining the variability of lead fragmentation and deposition associated with distinctly different categories of bullets and firearms used to harvest deer in Minnesota. Although the extent of contamination will likely vary based on caliber (and thus bullet weight), we believe measuring specific types of bullets (Rapid Expansion, Controlled Expansion, and Copper) will provide meaningful results that can be generalized among various rifle calibers. It was not our intent to endorse or defame any particular bullet manufacturer. We selected bullets based on their advertisement and availability. In examining advertisements, bullets designed to rapidly expand should not differ based on manufacturer. For example, the soft point bullet is designed to expand rapidly and no manufacturer claims to retain more energy than another.

OBJECTIVES

- To examine the variability of bullet fragments in relation to the wound channel;
- To determine the level of bullet fragmentation before and after thoroughly rinsing the carcasses shot with rapid expanding bullets; and
- To estimate the level of contamination in muscle tissues in relation to the wound channel after rinsing the carcass with water.

METHODS

This study was initiated in the spring of 2008 and the goal was to have research results available by late summer 2008. It was logistically impossible to obtain an adequate sample size of deer in late spring/early summer 2008. Thus, we used domestic sheep as a surrogate to white-tailed deer. Domestic sheep are ruminants, anatomically similar to deer, and were readily available for this study. Further, domestic sheep have comparable weights to white-tailed deer; their weight and size would certainly classify the species as mid-sized game if domestic sheep were considered a game species.

Seventy-two euthanized, domestic sheep and 8 white-tailed deer were used for this study. We obtained euthanized sheep, marked the coat with a bulls-eye using non-lead based spray paint, then marked the carcass for identification purposes using spray paint. Each sheep was propped up in a broadside position then shot in the thoracic cavity at 50 m. The treatments for this study included: 1) Rapid Expansion Bullets, 2) Controlled Expansion Bullets, 3) Copper Bullets, 4) Shotgun, and 5) Muzzleloader. A .308 Winchester was used to test the first 3 treatments (Rapid Expansion, Controlled Expansion, and Copper Bullets), a 12 gauge shotgun was used to test the Shotgun treatment, and a 50 caliber muzzleloader was used to test the Muzzleloader treatment. The study included 2 treatments each of Rapid Expansion, Controlled Expansion Bullets, and Muzzleloader Bullets. Each of these treatments had bullets made by a different manufacturer (Table 1).

Eight deer were killed on 23 April 2008 using a .308 Winchester with Rapid Expansion bullets that weighed 150 grains. Deer were killed in Permit Area 101 and were transported to the Farmland Wildlife Research office to be stored in a walk-in freezer. Each deer was shot <100 m of the sharpshooter. These deer were not eviscerated until the animals arrived at the necropsy laboratory in July. Sheep that were shot with comparable bullets will be compared to the 8 deer harvested on 23 April 2008.

Bullet fragments were analyzed using radiography with techniques similar to those used by Hunt et al. (2006). We removed the hide of the eviscerated carcass, inserted a carbon fiber tube through the wound channel then took a radiograph on the exit wound side. To test the effects rinsing had on bullet fragment number, we thoroughly rinsed the carcasses that were shot with Rapid Expanding Bullets with water, inserted a carbon fiber tube through the wound channel then took a second radiograph. Due to logistical constraints, we did not take a second radiograph of sheep shot with non-Rapid Expansion Bullets. We measured the maximum distance of fragments in relation to the carbon fiber tube, counted the number of fragments, and calculated the proportion of fragments that were within 13 cm (5 inches) on all radiographs.

The extent of lead contamination in muscle tissue was determined by using similar methods as those used in Dobrowolska and Melosik (2008). We collected a muscle tissue sample from 5, 25, and 45 cm (18 inches) from the exit wound (Figure 1). To assess the effects rinsing has on lead contamination, we rinsed carcasses shot by all bullet types and collected another 3 muscle tissue samples at the same distances.

We also measured the diameter of the entry/exit holes on each carcass. These measurements will be used as a “killing power” index and are used to illustrate the potential effectiveness of each bullet type for killing deer. Finally, we measured the wound channel lengths (linear distance between the entry and exit wound) to determine if wound channel length has an effect on fragmentation patterns or lead concentration levels.

RESULTS AND DISCUSSION

Results related to fragmentation distances, fragmentation patterns, and lead levels were not available at the time this report was written. Thus, we can only provide descriptive statistics for the data that were available in late July. We anticipate receiving all data by mid-August and have a technical report available by late August 2008.

Although our domestic sheep weighed less than the white-tailed deer used for this study, entry and exit hole diameters, and wound channel lengths were comparable between the 2 species (Table 1). The caudal end of eviscerated carcasses likely explains most of the weight differences between the 2 species, thus, the similarity in wound channel distances and entry/exit hole diameters was not unexpected. Based on these data, we believe the differences found among treatments (i.e., bullet types) with the domestic sheep will be directly comparable to what we would have found using white-tailed deer.

Entry holes for the Rapid Expanding Bullets were approximately twice the diameter of entry hole diameters for Controlled Expansion Bullets (Table 1). However, exit hole diameter diameters were comparable between Rapid Expansion and Controlled Expansion Bullets. Entry and exit holes for Copper Bullets were nearly identical to those calculated for Controlled Expansion Bullets. This finding is logical since Controlled Expansion and Copper Bullets are designed and marketed as having the capability to “mushroom” similar to Rapid Expanding Bullets. However, they are designed to expand midway through the wound channel rather than immediately upon impact like the Rapid Expanding Bullets. These findings would suggest that the trauma caused by Controlled Expansion Bullets is similar to the trauma caused by Rapid Expanding Bullets on the exit hole side of the animal. However, the diameter of the wound channel caused by Rapid Expansion Bullets will be greater on the entry hole side of the animal and therefore, will likely create more trauma throughout the thoracic cavity. Conversely, the trauma inflicted by the Controlled Expansion Bullets on the exit hole side of the animal is clearly adequate to humanely kill a mid-sized game mammal.

Although we were not able to provide quantitative results related to bullet fragmentation patterns or to assess lead levels at the time this report was written, we do feel comfortable summarizing some of our direct observations from the radiographs. It was very apparent that there are differences between the number of fragments counted between the Rapid Expanding Bullets compared to the Controlled Expanding Bullets and the Copper Bullets. It was typical to see a “cloud” of fragments surrounding the exit hole for animals shot with both types of Rapid Expanding Bullets. In contrast, we probably counted <5 bullet fragments on the radiographs of sheep that were shot with Controlled Expansion and Copper Bullets. We believe no, or very few, fragments will be observed on many radiographs of sheep shot with Controlled Expansion or Copper Bullets.

The number of visible fragments from radiographs of sheep shot with Shotgun Slugs was low. Occasionally, we may have observed a fragment in close proximity of the exit wound. However, we believe the number of fragments counted on radiographs of sheep shot with Shotgun Slug will be less than the number of fragments counted on radiographs of sheep shot with Controlled Expansion and Copper Bullets. Clearly, the number of fragments counted on the radiographs of sheep shot with Shotgun Slugs will be less than the number of fragments counted on Rapid Expanding Bullets. While we are not certain, the results from the fragmentation counts from radiographs of sheep shot with Muzzleloader bullets will likely be somewhat comparable to the findings for sheep shot with Shotgun Slugs.

We feel comfortable reporting these preliminary findings, however, we caution the use of any of our results until all data are analyzed and interpreted. Our data related to lead levels in muscle tissue were not available at the time this report was written and we were not able to speculate about direct observations because, lead “dust” and fragments are not visible like fragments are on radiographs.

LITERATURE CITED

Dobrowolska, A., and M. Melosik. 2008. Bullet-derived lead in tissues of the wild boar (*Sus scrofa*) and red deer (*Cervus elaphus*). European Journal of Wildlife Research. 54:231-235.

Hunt, W. G., W. Burnham, C. N. Parish, K. K. Burnham, B. Mutch, and J. L. Oaks. 2006. Bullet fragments in deer remains: Implications for lead exposure in avian scavengers. Wildlife Society Bulletin. 34: 167-170.

Table 1. Average (SD) entry and exit hole diameters (in inches), wound channel lengths (distance between entry and exit holes in inches), and weights (in pounds) of white-tailed deer and domestic sheep shot with different bullet types and weapons, Minnesota, 2008.

Weapon	Bullet type	Species	N	Carcass weight	Entry hole	Exit hole	Wound channel
Rifle	Ballistic Tip	Deer	8	68 (9)	1.0 (0.6)	2.7 (0.9)	8.6 (1.2)
	Ballistic Tip	Sheep	10	43 (7)	1.0 (0.6)	2.0 (0.6)	8.9 (1.0)
	Core-Lokt	Sheep	10	34 (11)	1.1 (0.4)	1.9 (0.6)	7.2 (0.8)
	Hornady Interbond	Sheep	10	29 (7)	0.6 (0.2)	1.8 (0.5)	7.8 (2.4)
	Winchester XP^3	Sheep	10	45 (8)	0.7 (0.2)	1.7 (0.4)	9.3 (1.3)
	Barnes TSX	Sheep	10	38 (9)	0.8 (0.3)	2.0 (0.7)	7.7 (1.7)
Shotgun	Foster Slug	Sheep	10	48 (11)	1.3 (0.2)	1.7 (0.3)	7.8 (1.3)
Muzzleloader	Powerbelt	Sheep	6	37 (6)	0.9 (0.1)	1.2 (0.2)	6.0 (0.8)
	Hornady XTP	Sheep	6	46 (22)	1.3 (0.6)	1.7 (0.6)	7.4 (1.5)

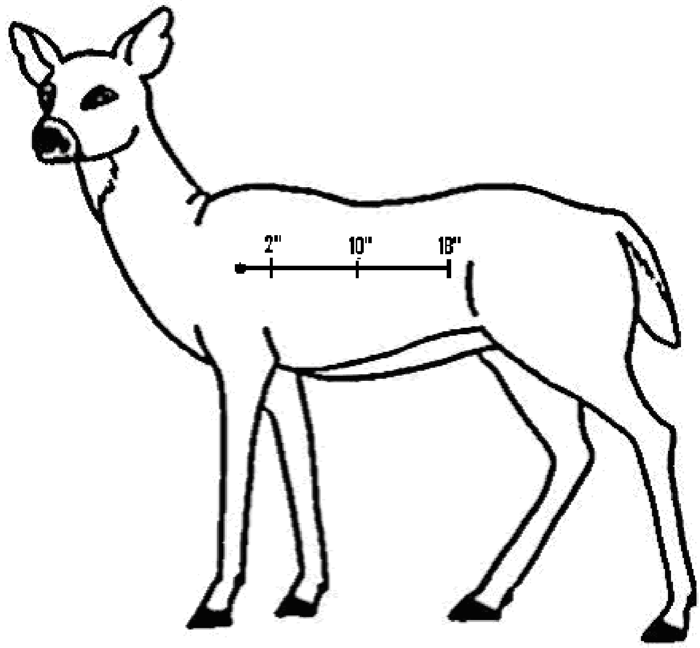

Figure 1. General locations on carcasses where muscle tissues were extracted in relation to the exit hole.