

The Cost of a Prickly Diet: Incidents of Porcupine (*Erethizon dorsatum*) Quills Embedded in Wolverine (*Gulo gulo*)

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The occurrence of North American Porcupine (*Erethizon dorsatum*) quills embedded in wild carnivores and domestic dogs is not rare; however, the prevalence of this occurrence and its consequences in wildlife are largely unknown. We examined 569 trapper-submitted Wolverine (*Gulo gulo*) carcasses for embedded porcupine quills. We observed quills in 4.6% of the wolverines, including all sex and age classes. We found quills throughout the body, and, in most cases, injury was not apparent. Observed complications, however, included bone proliferation and tissue damage to internal organs. Our data show that the occurrence of porcupine quills in Wolverine is not rare and demonstrate that, in a few cases, serious injuries may result from migrating quills.

Key Words: North American Porcupine; *Erethizon dorsatum*; Wolverine; *Gulo gulo*; quills

Introduction

Wolverines (*Gulo gulo*) are characterized as facultative scavengers of ungulates killed by other carnivores and opportunistic predators, responding to seasonally or locally abundant smaller prey (van Dijk *et al.* 2008; Mattisson *et al.* 2011). Occasionally, wolverines prey on North American Porcupines (*Erethizon dorsatum*; Magoun 1987; Lofroth *et al.* 2007); however, preying on porcupines may be risky.

The pelage of porcupines consists of quills, which are specialized hairs used for self-defense. Porcupine quills have a unique geometry, which serves two functions: easy penetration into tissue and strong tissue adhesion during removal (Cho *et al.* 2012). These functions are facilitated by microscopic backward-pointing deployable barbs. The barbs aid tissue penetration by creating local stress concentrations, thus reducing the force needed to cut tissue. The barbs facilitate tissue adhesion by bending radially away from the quill shaft when pulled, thus increasing frictional resistance in the tissue and making the removal of quills difficult (Cho *et al.* 2012). The combination of these two functions causes the quills to migrate deeper into the tissue, rather than fall out. Indeed, porcupine quills have been found deep in the body cavity and internal organs of other mammals (Quick 1953; Johnson *et al.* 2006).

Several species of carnivores are known to prey on or scavenge porcupine despite the risk of injury from their quills. For example, porcupines have been observed in the diet of wolverines (Banci 1987; Lofroth *et al.* 2007; Dalerum *et al.* 2009); however, the frequency of incidents of embedded quills has not been reported. Moreover, although complications from migrated porcupine quills have been documented for domestic pets (e.g., Johnson *et al.* 2006), they are largely unknown for free-ranging carnivores. Maser and Rohweder (1983) noted a lack of serious damage from porcupine quills embedded in Cougars (*Puma concolor*), Fishers (*Pekania pennanti*), and Western Spotted Skunks (*Spilogale gracilis*) that fed on porcupines.

A multi-year Wolverine carcass collection program provided us the opportunity to examine a large number of these animals for porcupine quills. Here, we quantify the occurrences of embedded porcupine quills and describe injuries attributable to migrated quills.

Methods

We obtained Wolverine carcasses from licensed fur trappers in Yukon, during the 2005–2006 to 2011–2012 fur trapping seasons. Carcasses were skinned by trappers and kept frozen at -20°C for no more than 6 months before necropsy. We conducted a gross examination of carcasses for embedded quills, along with other injuries and abnormalities. Major organs (heart, lungs, liver, kidneys and spleen) were dissected, except for the stomach and intestines, which were preserved whole and their contents were not searched for quills. We assessed the body condition of each animal based on internal fat deposits (Robitaille *et al.* 2012). We recorded the location of porcupine quills and apparent complications resulting from the quills. Quill-related injury was established by examining the immediate area around the quill for tissue abnormality and inflammation.

Results

We necropsied 569 wolverines, 26 of which (4.6%) had porcupine quills embedded in 38 unique locations. The annual number of incidents of wolverines with embedded quills ranged from zero to seven, increasing in the last 2 years. Porcupine quills were present in all sex and age classes of wolverines (Table 1). No significant differences in the percentage of wolverines with porcupine quills were found between age classes ($\chi^2 = 3.95$, $P = 0.556$) or sexes ($\chi^2 = 5.17$, $P = 0.395$).

Porcupine quills were embedded in various body regions of wolverines (Table 2). Quills were most often (53%) found in the abdominal cavity and associated organs, where they had presumably migrated through the stomach. Typically, quills were either sticking out

TABLE 1. The incidence of North American Porcupine (*Erethizon dorsatum*) quills in Wolverine (*Gulo gulo*) harvested in Yukon during seven winters (sample sizes in parentheses). Young animals were <2 years old.

Wolverine sex and age class	Number of wolverines with embedded quills (<i>n</i>)						
	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012
<i>Sex</i>							
Male	2 (48)	3 (50)	3 (66)	0 (55)	2 (65)	4 (49)	3 (45)
Female	1 (20)	0 (27)	0 (27)	0 (20)	2 (36)	2 (24)	4 (36)
<i>Age-Class</i>							
Young	1 (37)	3 (50)	1 (48)	0 (34)	2 (68)	4 (46)	4 (53)
Adult	2 (30)	0 (26)	2 (43)	0 (39)	2 (29)	2 (26)	3 (27)
Total	3 (68)	3 (77)	3 (93)	0 (75)	4 (101)	6 (73)	7 (81)
Overall %	4.4	3.9	3.2	0	4.0	8.2	8.6

Note: Age class of some specimens were not able to be determined, and consequently were excluded from age class summary in table.

TABLE 2. General location of North American Porcupine (*Erethizon dorsatum*) quills embedded in Wolverine (*Gulo gulo*) harvested in Yukon during seven winters, 2005–2012.

Location of quill	No. of events
Torso and legs	9
Head	7
Abdominal fat deposit	6
Kidney	5
Stomach (external)	4
Abdominal cavity (floating)	2
Heart	1
Liver	1
Lung	1
Spleen	1
Diaphragm	1

from the stomach or embedded in the intestinal fat deposits, but they were also observed in the kidneys, liver, spleen, and diaphragm. Quills were also commonly (42%) located in the torso and legs, probably indicating the initial contact with the porcupine. Two incidents (5%) involved quills embedded in the heart and lungs, where they could have migrated either through skin or via ingestion. Typically, when quills were found in a wolverine, the range was one to five.

Complications from migrated porcupine quills were often not apparent, and most affected wolverines appeared to have a normal body condition. Quills embedded in muscle tissue or floating within a body cavity were not associated with any signs of complication. However, quills that were embedded in organs, such as kidney, liver, lung, or heart, had often caused local tissue damage, such as hemorrhaging, inflammation, congestion, and adhesions. In one instance, a quill was encapsulated in the heart of a juvenile male, and this animal also suffered from an intussusception of the colon resulting in intestinal necrosis. Quills were also found in the kidney and abdominal cavity. This animal was emaciated, but how much the quills contributed to his poor condition is unknown. Another noteworthy case involved a juvenile female with quills embedded in her shoulder, sternal and mesentery fat deposits, liv-

er, and lung. The liver was locally inflamed and had hemorrhaged around the quill; the affected lung was congested and showed signs of pneumonia. This wolverine appeared lean, but the effect of the quills on her physical condition is unknown. Two other notable cases of complications involved bone proliferation, where quills had penetrated the periosteum of long bones. In these cases, the quills were encapsulated within the bone, which displayed obvious malformations (Figure 1).

Discussion

Porcupine has been reported in the diet of wolverines (Banci 1987; Lofroth *et al.* 2007; Dalerum *et al.* 2009) as well as other carnivores (Pollack 1951; Quick 1953; Daniel 1960; Maser and Rohweder 1983), although in low frequencies. Our data do not reflect the frequency of porcupines in the diet of wolverines, because the outcomes of encounters may have included consumption without acquiring quills or engagement without consumption. Further, our sample was based on trapped wolverines and may not be representative of the overall population. The incidence of porcupine quills in wolverines is likely higher than reported here, because we would have missed quills attached to the skin, which was removed by trappers before they submitted a carcass. Regardless, a substantial percentage of the wolverines in our sample (~5%) had encountered or consumed a porcupine, suggesting that such encounters are somewhat common, with no differences among sex or age classes.

To the best of our knowledge, no studies have examined the implications of embedded porcupine quills on the host wildlife species, presumably because injured wildlife are rarely encountered, diagnosed, or treated. A study of quill injuries in domestic dogs indicated complications in 32 (10.8%) of 296 cases, and increasing time between quill injury and initial treatment was associated with an increased risk of complications (Johnson *et al.* 2006). Consequently, the risk of complications in wildlife is probably higher. However, wild carnivores may also have learned to kill and process porcupines with minimal exposure to quills (Maser and



FIGURE 1. North American Porcupine (*Erethizon dorsatum*) quill embedded in tibia (A) and fibula (B) of wolverines (*Gulo gulo*). Bone proliferation around the quill had enclosed the quills holding them tightly in place. Photos: K. Melton.

Rohweder 1983). Severe injuries related to quills have been reported in some birds, including Golden Eagle (*Aquila chrysaetos*; Lano 1922), Great Horned Owl (*Bubo virginianus*; Wiley 1969), and Gray Jay (*Perisoreus canadensis*; Griffin 1952). These species do not typically feed on porcupines, and these reports probably represent isolated events in which inexperienced birds attempted to prey on or scavenge them.

Porcupine quills can cause a variety of immediate and delayed complications as documented for domestic carnivores, such as dogs. Common complications in dogs following a porcupine encounter include localized pain, inflammation, and discharge (Johnson *et al.* 2006). However, serious delayed complications can also occur in domestic dogs, such as quill migration into the brain (Sauve *et al.* 2012), joints (Brisson *et al.* 2004), and central nervous system (Schneider *et al.* 2010). Quill migration, with attendant complications in some cases, was similarly observed in our sample of wolverines.

The percentage of wolverines with embedded porcupine quills doubled over the last 2 years of our study. Reasons for this increase are unclear. No scientific data on porcupine population trends during our study were available. Anecdotal observations suggest that porcupine abundance was stable or slowly increasing through much of Yukon during this time. The impact of an ap-

parently stable or slowly increasing porcupine population on our observed rates of quill injuries in wolverines is unknown. Porcupine is an infrequent diet item for wolverines, whereas Snowshoe Hare (*Lepus americanus*) is a main prey item of wolverines in Yukon (J.-F. Robitaille, unpublished data), and, typically, predators that rely on Snowshoe Hare switch to alternative prey when hare populations are low (Keith and Cary 1991). The increase in incidents of quills in wolverines that we observed was in synchrony with a low phase in the Snowshoe Hare cycle in the region (Krebs *et al.* 2014). It may be that wolverines will more readily prey on porcupines when Snowshoe Hares are scarce. However, study throughout the complete hare cycle would be needed to evaluate this hypothesis.

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