REDUCING NON-TARGET MOOSE CAPTURE IN WOLF SNARES

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ABSTRACT: I investigated the characteristics of moose (*Alces alces*) bycatch in kill snares set for wolves (*Canis lupus)* in interior and south-central Alaska, USA. My objective was to design a kill snare that would reduce moose vulnerability and injury if captured without reducing its effectiveness for capturing wolves. I documented at close range (<30 m) snare encounters by captive moose in natural habitat at the Kenai Moose Research Center (MRC) in south-central Alaska. Moose contacted 153 cm or 183 cm snares (n = 184) with their chest–shoulder area (59.8%), neck-head region (34.2%), upper legs (3.8%), and along the ribs (2.2%). I documented the fate of moose following 225 snare contacts; 13.8% were captured by the nose (5.8%), leg (4.9%), or unknown (3.1%) with the remainder either knock-downs (65.3%) or push-asides (21.0%). Moose did not attempt to avoid snares. Of the 147 knock-downs, 86.4% formed a loop 15-38 cm in diameter that laid near the snow surface continuing to present a potential trap for moose. I also evaluated capture rates by loop size for wild moose in 3 study areas in interior Alaska. Capture rate and type were not influenced by snare loop size or snow depth in the wild or the MRC. Capture vulnerability of wild and captive moose was higher in snares that were knock-downs by other moose or wind. I subsequently developed a snare that incorporated an additional wire (diverter) placed at a height that allowed moose or any ungulate taller than the set height of a wolf snare to contact and push the snare away prior to contact. This design reduced the vulnerability of moose but not wolves to capture. I also placed a cinch stop at 24.1-26.7 cm from the end stop of the snare loop to reduce injury to moose and act as a breakaway system without reducing the snare's effectiveness for capturing wolves. Results of this study are applicable to areas where wolf or coyote (*Canis latrans*) snaring occurs in the presence of moose and other large hoofed mammals.

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Kill snares are an effective trap to catch wolves (*Canis lupus*), lynx (*Lynx canadensis*), fox (*Vulpes vulpes*), and coyotes (*Canis latrans*) (Phillips 1996, Roy et al. 2005, Blejwas 2006), and are used throughout Alaska (USA), Canada, and Russia. Although snares were found to be 10 times more selective than foothold traps for coyotes and lynx (Guthery and Beasom 1978), incidental captures occur (Proulx et al. 1994). Furthermore, wolf snares can be even less selective than snares set for smaller furbearers because cable diameter and loop circumference are larger, set height is higher, and the size and strength of a wolf require that minimum breaking forces must be high. Historically, the problem of snares not being selective has been a concern for wildlife managers and trappers (Phillips 1996), resulting in areas closed to snaring throughout North America (Shivik and Gruver 2002) due to concerns that indiscriminate capture could negatively impact other wildlife populations. Also, public pressure exists to improve snare selectivity (Traps, Trapping, and Furbearer Management, The Wildlife Society Technical Review 90-1, 1990) and this is an issue addressed by the international program Best Management Practices (BMP) for regulated trapping conducted by the International Association of Fish and Wildlife Agencies.

Moose (*Alces alces*)*,* caribou (*Rangifer tarandus*), and Sitka black-tailed deer (*Odo-*

coileus hemionus sitkensis) are caught in wolf snares every year in Alaska (Gardner 2007). In separate 5-year studies using radio-collared moose (75-125 active radios/yr), Boertje et al. (2009) and M. A. Keech (Alaska Department of Fish and Game (ADFG), unpublished data, Fairbanks) documented 0-3 moose killed/yr in wolf snares (0.5%/yr). Wolf trapping was common in both study areas with snaring the preferred capture method.

Based on my 15 years of experience releasing nearly 40 moose from snares and discussions with other Alaskan biologists, I concluded that most moose restrained in wolf snares die either at the capture site or from frozen limbs or nose subsequent to release. For example, Steve DuBois (ADFG, personal communication) radio-collared and released 4 moose caught in snares that were without obvious injury, yet died 2 days later. Although necropsies were not performed, the timing of deaths indicates that death was probably due to complications associated with restraint in the wolf snare.

Previous studies found that accidental ungulate catch in coyote snares could be reduced through trapper education and use of snares with improved selectivity (Phillips et al. 1990, Phillips 1996, Roy et al. 2005). In Alaska, development and testing of wolf snares designed to release moose and caribou, but restrain wolves, has been ongoing since 1993 by ADFG and private trappers. One difficulty in designing a breakaway wolf snare is the trade-off between achieving desired selectivity and maintaining acceptable efficiency for wolves, because wolves and moose exert powerful forces on the snare when captured.

Two prototypes, the Thompson split lock (Thompson Snares 2009) used with 0.28 cm diameter cable and the camlock soft pin breakaway designs (Fig. 1), showed promise in the laboratory and were used as part of a wolf control program by ADFG in 1993-1994. During the program 30 wolves, 9 moose, and 5 caribou were caught in snares with the Thompson split lock breakaway mechanism. Of these, 29 wolves (96.7%), 6 moose (66.7%), and 3 caribou (60.0%) did not escape. I evaluated these data using Fisher's exact tests (FET) and found that the release rate was higher for moose (P = 0.03) and caribou (P = 0.047) than wolves; however, the restraining rate of moose and caribou remained unacceptably high. Three wolves were caught by the camlock soft pin design and 1 escaped due to the mechanism release; no moose or caribou were caught by this design.

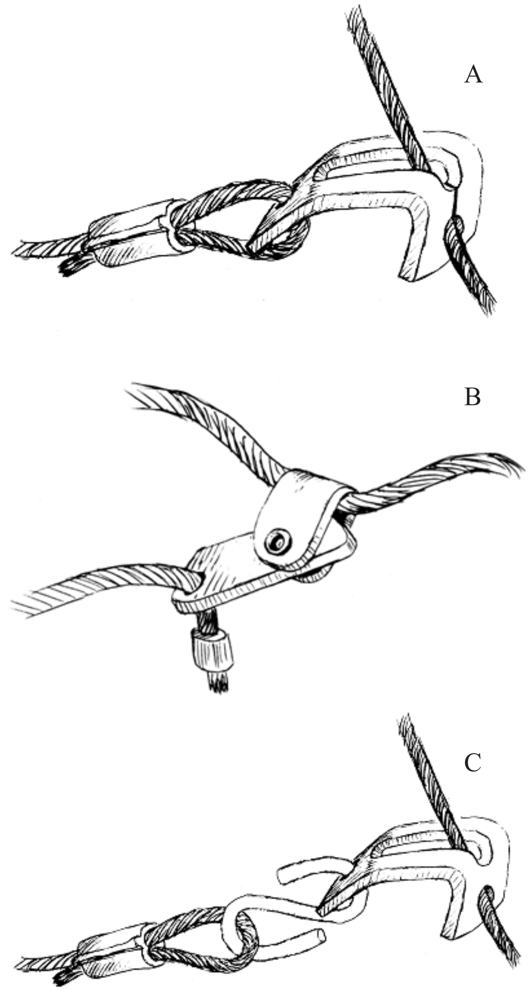

Fig. 1. Common breakaway mechanisms used by Alaskan trappers on wolf snares: (A) the Thompson split lock, (B) Camlock soft pin, and (C) S-hook.

Alaska trappers continued to improve ungulate release from wolf snares with a variety of breakaway mechanisms, most commonly a Thompson split lock used on a smaller diameter cable (0.24 cm) or S-hooks with varying breakaway strengths (Fig. 1). A trapper survey conducted by ADFG (Blejwas 2006) suggested that these breakaway systems worked for leg-caught moose, unless the moose had entangled the snare wire around flexible brush and could not generate enough force to break the release mechanism; moose caught by the nose or neck rarely broke free. Moose that remain restrained were vulnerable to injury and death due to freezing limbs at the snare attachment point. These deficiencies illustrated the need for a wolf snare design that minimized moose capture, particularly by the nose, and reduced the chance of injury when the breakaway mechanism failed.

These findings were consistent with results from studies that evaluated breakaway snare performance for capturing coyotes and releasing deer (*Odocoileus hemionus* and *Odocoileus virginianus*; Phillips et al. 1990, Phillips 1996, Roy et al. 2005). Roy et al. (2005) documented 74-88% release rates of deer using snares with the National 813 S-hook as the breakaway device. Deer that remained restrained were mostly fawns and all were caught by the neck. Phillips et al. (1990) found that coyotes and deer fawns generated similar force on a snare and concluded it would be difficult to design a system that released all deer yet restrained coyotes.

Previous efforts to reduce the accidental restraint of moose in wolf snares and other ungulates in coyote snares were to design breakaway systems that allow these ungulates to escape. Although completely eliminating moose capture by wolf snares is improbable, snares could be made more selective and humane if differences in behavior or physical stature of moose related directly to modifications that reduced their capture vulnerability. Accounting for behavioral differences proved beneficial in reducing incidental capture by other snare types (Proulx et al. 1994).

My primary objective was to design a wolf snare that would be less accessible to moose and contain a breakaway system that would minimize injury without reducing its effectiveness for catching wolves. Snare effectiveness for any new design needs to be consistent with current designs to be accepted by trappers (Naylor and Novak 1994). I took an innovative approach by directly observing hundreds of moose–snare encounters at close range (<30 m) in natural habitat to develop and test snare designs. My original hypotheses were: 1) wolf snare loop-size affects moose vulnerability to capture, 2) moose were equally vulnerable to being caught by the nose or leg in wolf snares, and 3) moose became more vulnerable to wolf snares as snow depth increases. The primary contributions of this study to wildlife research and management are: 1) demonstrating that repeated direct observations of ungulate–snare encounters are invaluable for designing effective snares that minimize the chance for bycatch of ungulates, 2) the importance of reducing vulnerability to capture and incorporating an effective breakaway mechanism, and 3) the development of a wolf snare that will likely protect moose and other ungulates from being captured without significantly reducing effectiveness for wolf capture. Results from this study will benefit the ongoing BMP process and be directly relevant to areas throughout the world that have wolves, large ungulates, and wolf trapping with kill snares.

STUDY AREA

I field tested various designs of wolf snares on captive moose at the Kenai Moose Research Center (MRC) in south-central Alaska and wild moose on the Tanana River Flats in Game Management Unit (GMU) 20A in interior Alaska (Fig. 2). The MRC allowed me to observe 100s of moose–snare encounters in a relatively short period of time, while in GMU 20A I evaluated snares in habitat and circumstances directly comparable to wolf trapping in interior Alaska. The primary overstory–shrub vegetation types at the MRC were paper birch (*Betula paperifera*), alder (*Alnus crispa*), willow (*Salix* spp.), and spruce (*Picea mariana* and *P. glauca*). Snow depths were 10-15 cm in February 2005 and 40-50 cm in January 2007. Trappers commonly set snares in these vegetative types and snow conditions in south-central Alaska.

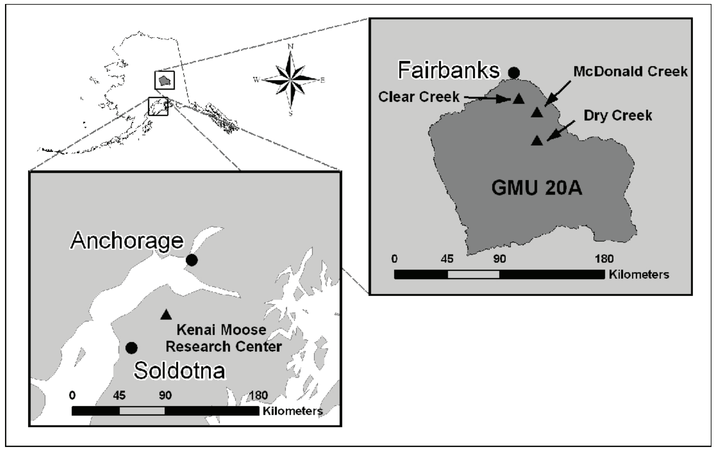

Fig. 2. Study areas were located at the Kenai Moose Research Center, ca. 30 km northeast of Soldotna, Alaska and in Game Management Unit 20A south of Fairbanks, Alaska, USA.

I tested snares in 3 areas within central GMU 20A that supported high moose densities (>800/1,000 km^2; Boertje et al. 2007) and were adjacent to areas trapped commonly for wolves. The primary vegetative types in the Dry Creek area were dwarf birch (*Betula nana*), willow, alder, and paper birch; spruce, paper birch, willow, dwarf birch, and alder were the common overstory-shrub species in the Clear and McDonald Creek areas. These areas were representative of habitats and climates commonly trapped in interior Alaska (Gasaway et al. 1983, 1992). Snow depth was reasonably similar in the 3 areas during snare testing, ranging 28 (December 2005)-56 cm (March 2006).

METHODS

Moose Vulnerability to Wolf Snares

On 1-4 February 2005 and 6-9 January 2007, I observed moose-wolf snare encounters at the MRC by setting 153 cm and 183 cm wolf snares in areas that maximized the chance that moose would encounter the snare (areas of highest moose use), but in a manner that mimicked typical snare sets for wolves. I used these loop sizes because they are the most commonly used in Alaska, are effective in catching wolves by the neck, and are the most readily available from commercial snare dealers. I set the snares following methods used by successful wolf trappers including dying and boiling the snares and setting them in a manner that they blended with the surrounding vegetation. Each set included 1-24 snares, closely divided between 153-cm and 183-cm loop sizes; 3-10 moose were monitored daily. When a group of moose moved beyond observation, I pulled the snares and reset them in another area.

I simulated the standard method of Alaskan wolf trappers (Alaska Trappers Association 2007) by setting both 153 and 183 cm circumference loop snares at 46 cm above the supportive surface of the snow. This height has proved effective in promoting neck catches by causing wolves to contact the bottom of the loop with their chest.

I recorded the initial contact point of a moose encountering a snare and described the characteristics of the encounter including snare loop size, snow depth, fate, and moose reaction. I categorized the fate of a moose-snare encounter as knock-down, push-aside, or caught. A knock down occurred when a moose contacted the snare and caused it to drop from its original height and form a smaller loop, pushed aside was when the moose contacted the snare but it returned to its original position and retained its loop size. To prevent restraining or injuring of moose, I modified each snare by removing the nut or stop behind the lock (Fig. 3). This modification allowed the test snare to cinch normally but the lock would slide off the cable quickly (<10 sec) freeing any captured animal with minimal discomfort. This approach also minimized learned behavior effects.

I compared moose capture rates (moose caught/encountered snare) and capture types (nose, neck, and leg) between wolf snares with 153-cm and 183-cm loop sizes at 2 different snow depths (46 cm and 10 cm). For each catch, I recorded the snare loop size and capture type. Initially I would reset the snare attempting to increase encounters and captures. However, there were incidences when a different moose would encounter a previously knocked-down snare and become caught by the leg. To examine the capture rate in previously knocked-down snares (another moose or wind), I recorded the circumference and position of the resulting loop following 18 knock-downs and evaluated the vulnerability of subsequent moose contacting the fallen snare.

From 30 December 2005-31 March 2006, I set and monitored 34 153-cm and 30 183-cm circumference loop snares divided among the 3 study sites (8-12 of each type/site) in GMU 20A. I purposely set individual snares along natural trails (simulated trail set) or in a gang set with 6-11 snares blocking off most of the natural trails in a 30 m radius (simulated bait-kill set). Both snare sizes were placed together, but not always in equal numbers, to evaluate moose capture rates by snare loop size. To be consistent with check times followed by most Alaskan trappers in areas without a defined check period, I waited at least 7 days and as long as 21 days due to periods of severe bad weather. Using tracks in the snow and position of the snare and lock in relation to the original set, I determined if a snare was encountered by a moose and was either knock-down, push-aside, or had caught the moose.

Snare Modifications to Reduce Moose Capture by the Nose

I used the results from the moose-snare encounter tests conducted at the MRC to design a wolf snare that reduced moose vulnerability to capture. I attached a 2.30 mm diameter "diverter wire" to standard 153-cm wolf snares so that it extended 70 cm perpendicular to the plane defined by the snare loop, at an angle 10-20^{o} from the horizontal plane tangent to the top of the snare (Fig. 4). The intent was for a moose to contact the wire with its nose or chest, and push the snare away before its nose entered the noose. Length of the diverter wire was based on measuring the distance from tip of nose to chest on 3 taxidermy-mounted adult male moose (≥6 yr). I used the longest measurement (70 cm) to ensure that a moose would contact the diverter before the snare.

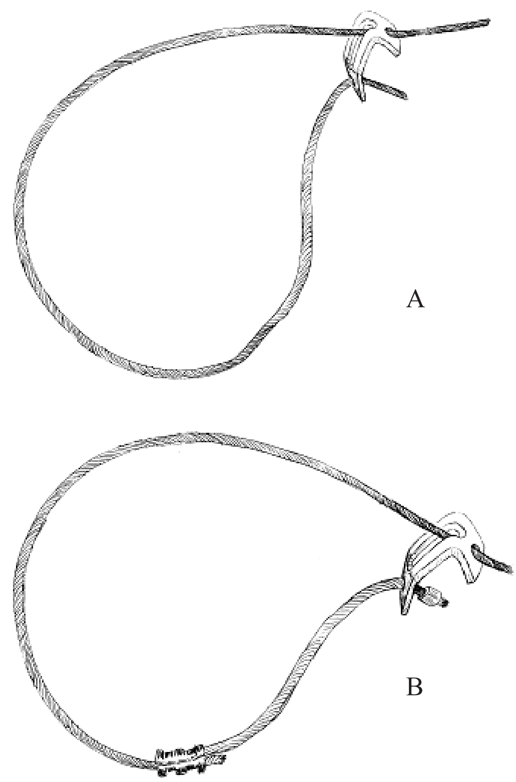

Fig. 3. Test snare without a cable end stop (A) that allows the lock to slide off the cable if an animal is caught to prevent injury, and a snare that includes an end stop (B).

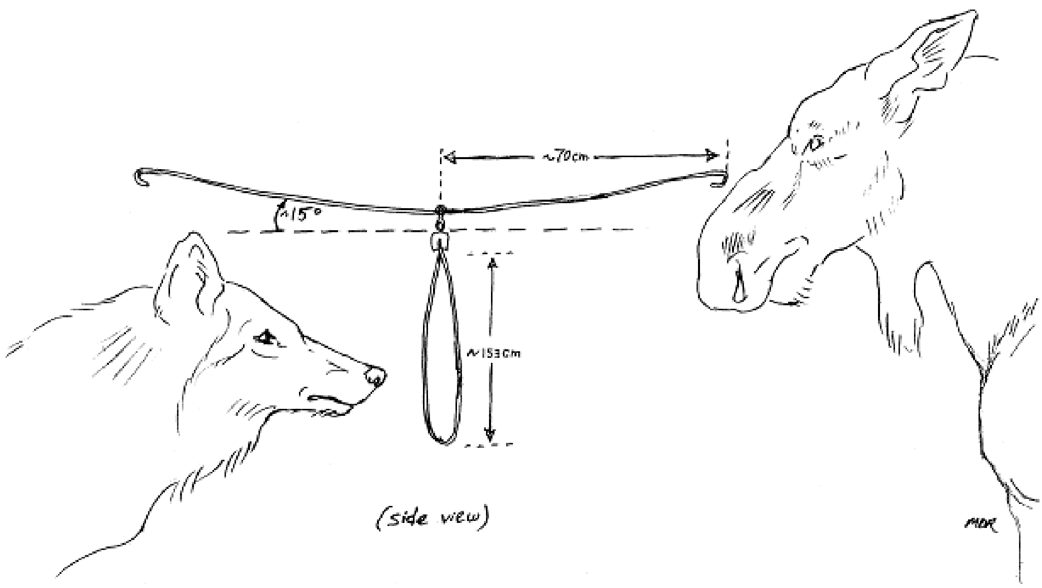

Fig. 4. Modified wolf snare showing the diverter wires that extend ca. 70 cm perpendicular to the snare loop at a 10-20^{o} angle from the top of the snare. The positioning of the diverter wire allows wolves to travel underneath without contact and moose or large ungulate to contact the wires causing the snare to be pushed away from the nose. The ends are recurved to minimize chance of injury when encountered by a moose.

I compared capture rates and types between the diverter test snare design and 153-cm and 183-cm loop standard snares by setting diverter snares alongside these snares. Since the snares in GMU 20A were not checked for 7-21 days, the number of days that a snare was a knock-down and could potentially capture moose was unknown.

I tested if diverter snares would be more prone to being knock-downs by wind or snow due to the additional wire because increased knock-down rates would reduce snare efficiency for wolves and possibly increase vulnerability of moose to leg capture. I compared the knock-down rate between diverter snares and standard 153-cm and 183-cm snares due to wind in the Clear Creek and McDonald Creek study areas in GMU 20A. Data from Dry Creek were not included in my analysis because the periods of observations were not aligned with those of the other 2 areas. In the Clear Creek area, 11-12 diverters and 10-11 standard snares (153-cm or 183-cm) were monitored for 6 periods of 8-29 days (99 total days and 2,291 trap nights). In the McDonald Creek area, 8 diverters and 36 standard snares (153-cm or 183-cm) were monitored for 6 periods of 7-29 days (95 total days and 4,224 trap nights). Period length varied due to periodic cold snaps (<-40^{o} C for 6-13 days) that precluded safe travel.

I categorized a snare as a knock-down from wind if it had dropped from its original set position if animal tracks, measurable snowfall, and high wind (snow off trees, drifting) were not evident. I timed my visits after high wind events but before subsequent snowfall. I censored the data in only 2 instances because I could not discern if wind or animals caused the knock-down.

To compare selectivity and effectiveness of diverter snares in the 2006-2007 trapping season, I contracted 2 trappers in GMU 20A to use 100 diverter snares in their normal trapping activity. They were trained in data collection protocol and provided with data forms; they recorded the number of diverters set at each site, how each snare was anchored (flexible or solid anchor), species caught, and fate of captured wildlife. They also interpreted tracks to document if wolves avoided the set. Location, snare anchor point, and the number of snares were not random; each trapper made decisions from site-specific wolf sign and available vegetation to anchor the snare.

Snare Modifications to Reduce Injury and Death for Leg-caught Moose

To reduce injury to leg-caught moose and other ungulates, I investigated the possibility of incorporating a cinch stop that would prevent the snare from cinching tight on a moose leg but not reduce the effectiveness in killing neck-caught wolves. I selected the placement of the cinch stop by comparing loop sizes that killed trapper-caught wolves by the neck (n = 62) with the circumferences of loops cinched on hunter-killed moose legs (n = 9). I also asked trappers to record sex of wolves and if practical, provide the carcass or front leg to age wolves (pup, adult) using the epiphyseal closure on the radius and ulna (Rausch 1967). Trappers in GMU 20A also caught known-aged wolves marked in another study (Gardner and Beckmen 2008). To determine if the cinched down loop size differed due to snare cable size or sex and age of the wolf, I compared final loop circumferences of 0.24, 0.28, and 0.32 cm diameter snare from wolf kills. Wolves were classified as pups (5-11 months), subadult (17-22 months), or adult. My rationale for these analyses was if a certain size cable cinched tighter, or if the circumference of cinched loop size on certain age or gender of wolves is comparable to a moose leg, the position of the cinch stop may need to vary by cable size or not be a viable option. To determine the minimum loop size for leg-caught moose, I attached a snare cable to the front and rear legs of hunter-killed 5 month calf (n = 1), adult female (n = 4), and adult male (n = 4) moose at the most common catch point on the leg, cinched it snug but not so tight to cause injury, and measured the final loop circumference.

I then tested the cinch stop snare in the laboratory by cinching the snare down on legs of a 5 month calf, an adult female moose, an adult male moose, and a simulated wolf neck (Phillips et al. 1990, Roy et al. 2005). I observed that if the lock contacted the cinch stop, the lock deformed (flattened out) as force was added; this led me to investigate whether this contact force would be sufficient for the cinch stop to also function as a breakaway mechanism. I hypothesized that the breaking force would be less when the lock came into contact with the cinch stop, which would occur when cinched down on a leg of a moose or a smaller ungulate, thus increasing the chance of release. I constructed the breakaway component by cutting the snare within the loop at either 24.1 or 26.7 cm from the cable end stop (circumference range of largest moose leg and smallest wolf neck) and inserting a 0.24 cm double ferrule on 0.24 cm snare cable, or 0.32 cm double ferrule on 0.28 and 0.32 cm snare cables. The ferrule was attached by swaging each end using a 0.24- or 0.32-cm swage tool. Each ferrule was inspected to ensure that inconsistent manufacturing was not a factor in breaking strength.

I initially evaluated breaking strengths of the cinch stop breakaway (CSB) mechanism in the laboratory by measuring the breaking force by cinching down CSB snares until the mechanism released on a front leg collected from a female moose (circumference = 22.7 cm) and a simulated wolf neck (i.e., 27.9 cm circumference steel pipe wrapped with cotton; Phillips et al. 1990, Roy et al. 2005). The simulated wolf neck was 32.6 cm in circumference matching the mean neck size from 62 wolves collected from trappers; cotton was added to allow the snare cable to embed and absorb energy to better mimic when a wolf is snared by the neck, and to make it more similar to a moose leg. I measured the breaking force necessary to break the CSB using a Dynalink dynamometer strain gauge (Model 7200; Measurement System International, Seattle, WA, USA) attached to a hydraulic tee cylinder (Model SAE-9012; Prince Manufacturing Corporation, Sioux City, IA, USA). I tested the CSB system on 1×19 twist 0.24 cm, 0.28 cm, and 0.32 cm snare cable. Each snare type was tested 20 times each on the simulated wolf neck and a moose leg.

I compared the breaking strength for the CSB for 0.24, 0.28, and 0.32 cm diameter cable sizes to the 0.28 cm diameter Thompson split lock design field and laboratory tested during the wolf control program by ADFG in 1993-1994 (ADFG, unpublished data). The breaking force of the Thompson split lock was determined by different researchers at ADFG with the same methodology and equipment as described above. The measured breaking forces for all the tested breakaway types do not necessarily replicate the actual force that captured moose or wolves exert on a snare, but indicated possible differences that were field-tested.

I first tested the efficiency of the CSB mechanism for moose at the MRC in 2005 by catching 2 male moose by the leg in a natural setting. The CSB was attached on a 0.28 cm 1×19 snare. I documented how moose were caught, their behavior while caught, and the elapsed time to release. The efficiency of the CSB snare was further tested in the 2005-2006 trapping season by the 2 contract trappers. They set these snares under the same conditions explained for the diverter snares. To maximize the number of encounters and catches of moose and wolves, only CSB snares without diverter wires were set by these trappers recognizing the possibility of nose catches.

Moose capture using the test snare without the end stop complied with acceptable methods for field studies adopted by the American Society of Mammalogists (Animal Care and Use Committee 1998, ADFG Protocol #06-04). Field testing by trappers of the diverter and breakaway snare designs as kill snares (end stop attached) followed state trapping regulations but was not included under the protocol.

Data Analysis

I used the software R® (R Development Core Team 2008) to perform statistical analyses. I used chi-square tests (Cochran 1977), or FET if any expected cell count was <10 in 2×2 contingency tables, (single degree of freedom) to identify difference in capture rate and capture type by snare type, snow depth, captive and wild moose, and to distinguish how moose initially contacted different snare types. I employed both chi-square tests and FETs when expected cell counts were low as a check against the potential for the exact tests to be overly conservative (D'Agostino et al. 1988). Lack of balance in the experimental design precluded using generalized linear models to test for interactions due to snow depth when examining capture rates and types. To test for differences in capture type, I followed the method specified by Scott and Seber (1983) that accounts for the covariance associated with sampling a multinomial distribution. I used *t*-tests to compare breaking forces for the different breakaway mechanisms. I used generalized linear models to assess the effect of a diverter on the binary response, knock-down by wind, or not. I used quasi-AIC (QAIC) (Lebreton et al. 1992) and likelihood ratio tests to compare these models and present the goodness-of-fit metric, $\hat{c}$.

RESULTS

Moose Vulnerability to Wolf Snares

I documented 304 moose–snare encounters at MRC through direct observation or from tracks in the snow and found no evidence that moose modified their behavior due to the presence of snares; moose did not shy away or abruptly change course when encountering a snare. I observed 184 encounters between moose and standard wolf snares; the impact points were the chest-shoulder area (59.8%; SE = 3.6%), neck-head (34.2%, SE = 3.5%), legs (3.8%, SE = 1.4%), or ribs (2.2%; SE = 1.1%) (Table 1). I documented the fate through observation and by tracks

Table 1. Observed impact points where captive moose initially contacted 153-cm loop, 183-cm loop, and diverter wolf snares (n = 207). This phase of the study was conducted at the Kenai Moose Research Center, Alaska, February 2005 and January 2007.

		Impact point							
	Contacts	Chest–Shoulder		Neck–Head		Ribs		Legs	
Snare type	n	n	%	n	%	n	%	n	%
153-cm loop	112	67	59.8	36	32.1	4	3.6	5	4.5
183-cm loop	72	43	59.7	27	37.5	0	0	2	2.8
Subtotal	184	110	59.8	63	34.2	4	2.2	7	3.8
Diverter	23	17	73.9	6	26.1	0	0	0	0

of 225 moose-snare encounters; 65.3% (SE = 3.2%) were knock-downs, 20.9% (SE = 2.7%) were push-asides, and 13.8% (SE = 2.3%) were caught moose (Table 2).

Snare impact points were not related to snare loop size. For 183-cm snares, moose initially contacted their neck-head area 37.5% (SE = 5.7%) of the time, similar to the initial contact rate of 32.1% (SE = 4.4%; Table 1) for 153-cm snares ($\chi^2 = 0.56$, $P = 0.46$). Capture rate was not affected by snare loop size ($\chi^2 = 1.31$, $P = 0.25$; Table 2); capture rates of the 153- and 183-cm loop snares were 17.3% (n = 84, SE = 4.2%) and 11.8% (n = 147, SE = 2.7%), respectively. Snow depth did not influence capture rate ($P = 0.83$, FET; Table 3).

Capture rates of wild moose by 183-cm loop snares (15 of 35, 42.9%, SE = 8.5%) were not different ($\chi^2 = 0.99$, P = 0.32) from that with 153-cm loop snares (12 of 38, 31.6%, SE = 7.6%). Capture rate of wild moose (27 of 73, 37.0%, SE = 5.7%) was higher than that of captive moose (31 of 225, 13.8%, SE = 2.3%; $\chi^2 = 18.9$, P <0.001).

I was able to determine capture type in snares encountered at the original set height for 24 of 31 (77.4%) moose caught at the MRC; 54% (SE = 10.4%) were caught by the nose and 46% (SE = 10.4%) by the leg (Table 2). Unobserved captures occurred due to the short time necessary to escape the test snare, as well as attempting to observe multiple moose simultaneously. All nose catches occurred in snares encountered at

Table 2. Capture rate and type in 153-cm, 183-cm, and diverter wolf snares measured by observing captive moose at the Kenai Moose Research Center, Alaska, February 2005 and January 2007.

		Fate						Capture type[a]			
	Snares encountered	Knocked-down		Pushed-aside		Caught		Nose		Leg	
Snare type		n	%	n	%	n	%	#	%[b]	#	%[b]
153-cm loop	144	104	72.2	23	16	17	11.8	7	5	5	3.6
183-cm loop	81	43	53.1	24	29.6	14	17.3	6	7.6	6	7.6
Subtotal	225	147	65.3	47	20.9	31	13.8	13	6	11	5
Knock-down (153- and 183-cm snares)[c]	18	n/a		n/a		6	33.3	0	0	6	0
Diverter	42	40	95.2	2	4.8	0	0	0	0	0	0
Diverter knock-down[c]	19	n/a		n/a		0	0	0	0	0	0

[a] The sample size of capture type is less than # caught because all captures were not observed.

[b] Percent capture determined without including unknown capture types.

[c] Snares that were previously knocked down but left until another moose encounter occurred.

original height; all leg catches occurred in a knock-down when a moose stepped in with its front (n = 3) or hind foot (n = 8). The proportion of nose and leg catches did not differ ($p_{leg} - p_{nose}$ = –0.08; 95% CI = –0.48, 0.32; n = 24). Capture type did not depend on snare loop size (P = 1, FET; Table 2) or snow depth (P = 0.38, FET; Table 3).

Moose were caught more frequently by knock-downs from another moose or wind (6 of 18, SE = 11%; Table 2) than snares encountered at original set height (31 of 225, SE = 2.3%; P = 0.04, FET); leg captures occurred only in previous knock-downs. At the MRC, 86.4% (102 of 118, SE = 3.2%) of knock-downs by moose formed loops 15-38 cm in circumference, remaining in the trail at snow level and available for leg captures. There was no difference in the number of knock-downs of 153-cm (6 of 74, SE = 3.2%) and 183-cm snares (0 of 36; P = 0.17, FET) forming loops <15 cm.

Snare Modification to Reduce Moose Capture

I observed 23 moose-diverter snare encounters at the MRC and the impact points were either at the chest-shoulder (73.9%) or neck-head area (26.1%; Table 1). Based on observations and tracks, moose contacting a diverter wire caused knock-downs in 40 of 42 cases (95.2%) with 2 push-asides (4.8%; Table 2). No moose contacting a diverter snare (n = 42) was caught, and the capture rate was less than that for standard snares (P = 0.007, FET; Table 2). Assuming the next encounter with a diverter snare would result in a capture, the capture rate for the diverter snares would have remained lower than that for standard snares (P = 0.04, FET).

Moose knocked down diverter snares more frequently than standard snares (P < 0.001, FET), and once knocked down, 85.0% formed 15-38 cm circumference loops on the snow. Due to the high knock-down rate, I hypothesized that moose would be more vulnerable to leg catches in diverter snares; however, no moose at the MRC was caught in a knock-down from diverter snares (n = 19) compared to 6 of 18 caught in knock-downs from standard snares (P = 0.008, FET). I observed 6 knock-downs from diverter snares contacted by moose, and in all cases the diverter wire was still contacted first causing the snare loop to move away. Encounters of 1-2 additional contacts caused no damage to the diverter wire.

The capture rate of wild moose in diverter snares (without a cable end stop) was 12.1% (7 of 58) in GMU 20A. As snares were unattended, I was not able to determine capture types and the frequency of encounter for knock-downs of diverter snares. Diverter wires on the 7 snares that caught moose were bent and no longer functional, but I could not confirm if this damage was pre- or post-capture. Moose were only caught in diverter snares unchecked 12-21 days; no moose were caught in snares unchecked 7-11 days. Standard test snares set in GMU 20A caught moose more frequently (27 of 73) than diverter modified snares (P = 0.002, FET).

The 2 contracted trappers caught and killed 9 wolves by the neck after setting 96 diverter snares in GMU 20A in December 2005-March 2006. No moose encountering

Table 3. Catch rate and catch type of captive moose in standard wolf snares at 2 snow depths at the Kenai Moose Research Center, Alaska, February 2005 and January 2007.

Snow type	Encounters	Catch rate (%)	Nose catch (%)	Neck catch (%)	Leg catch (%)	Unknown
Deep snow[a]	218	12.8	9 (4.3)	0	12 (5.7)	7
Shallow snow[b]	62	11.3	4 (6.6)	0	2 (3.3)	1

[a] Snow depth ca. 46 cm.

[b] Snow depth ca. 10 cm.

a diverter snare was captured (n = 9); no wolf or moose approached any other snare. Based on binomial probabilities (95% confidence level), the diverter snares would catch at least 71% of wolves and prevent capture of ≥71% moose (Proulx et al. 1994)

Diverter snares were not knocked down more by wind than standard 153- and 183-cm snares. The global generalized linear model, with QAIC = 95.1, indicated that area and period effects were significant or marginal (area: $x_1^2 = 4.5$, $P = 0.03$; period: $x_4^2 = 8.9$, $P = 0.06$), while the diverter effect and the area:period interaction were not significant (diverter: $x_1^2 = 1.4$, $P = 0.23$; area:period: $x_4^2 = 2.8$, $P = 0.58$). A comprehensive comparison of realistic models indicated that the best fit model included area as the only covariate (QAIC = 84.4 and weight of evidence = 48.2%). The goodness of fit statistic ($\hat{c}$) was 1.7 for the best model indicating reasonable fit.

Snare Modifications to Reduce Injury to Moose

Loop circumference of cinched snares on moose legs was 23.5-24.1 cm for 3 adult males, 22.5 cm for 1 yearling male, 20.9-22.7 cm for 4 adult females, and 19.7 cm for 1 calf; average cinch size was 22.4 cm (SD = 0.32). The average loop circumference of neck-caught wolves (n = 62) was 32.6 cm (SD = 2.48, range = 26.7-38.7); the smallest was on a 5 month old female (22.7 kg). The cinch stop could be placed 22.7-26.7 cm from the cable end stop based on the age (subadult/ad) and sex of 31 of these wolves; therefore, I placed the cinch stop at either 24.1 cm or 26.7 cm for testing.

The breakaway force required to release the CSB mechanism depends upon snare cable size, circumference of the cinched loop, and proximity of the lock to the CSB mechanism (Table 4, Fig. 5). On a moose leg, the cinched loop stopped at the cinch stop as the lock contacted the mechanism. On the simulated wolf neck, the cinched loop size was 32.6 cm and the lock stopped 5.9-8.5 cm from the CSB. The breakaway force was higher on the simulated wolf neck than the moose leg, increased with cable size, and decreased when the CSB mechanism was placed further from the cable end stop ($P \leq 0.01$; Table 4). The breaking force for CSB equipped snares was less than the breaking force of the 0.28-cm snares with a Thompson split-lock (325.4 kg; SE = 8.2, $P < 0.001$), regardless of cable size and CSB placement (Table 4).

During the initial field test a 12 year and a 3 year old male moose were caught at the MRC in a CSB snare with the mechanism placed at 24.1 cm and attached with solid anchor. The 3 year old male was caught by the hind foot and broke free in <2 sec; the 12 year old male was caught by the front leg and broke free in 2 min and 21 sec. Upon capture, the 12 year old male tangled the snare wire around surrounding flexible shrubs preventing it from pulling directly against the solid anchor; the lock was tight against the breakaway mechanism but the snare loop rotated around the foot. After inspecting the leg and verifying that the restraining loop caused no injury, I determined that the design was adequate for further testing by the 2 contract trappers.

The contract trappers set 24.1 cm (n =

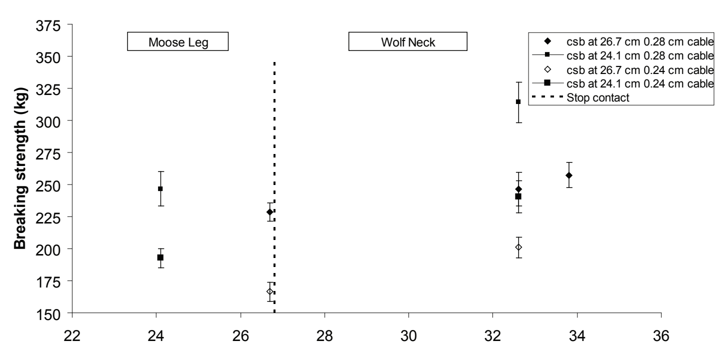

Fig. 5. Comparisons of breaking strengths for a cinch stop breakaway mechanism by placement and cable size.

Table 4. Breaking strength (kg) of breakaway snares used on simulated wolf necks and actual moose legs in Fairbanks, Alaska, 2004–2006. Each snare cable diameter combination was tested 20 times.

Type/location	Cable size	Breaking strength (kg)			
		Moose	SE	Wolf	SE
CSB/24.1[a]	2.4	192.6	3.53	240.4	5.97
	2.8	246.6	6.44	314	7.43
CSB/26.7[b]	2.4[a]	166.4	3.62	201.1	3.86
	2.8[b]	228.4	3.46	246.5	6.21
	3.2[c]	276	6.89	312.9	8.2
Split lock[c]	2.4			264.2	3.6
	2.8			325.4	8.2
S-hook[d]	2.4			198.5	12.2

[a]Cinch stop breakaway (CSB) located 24.1 cm from the cable end stop.

[b]Cinch stop breakaway located 26.7 cm from the cable end stop.

[c]Thompson split lock.

[d]S-hook attached to a Thompson lock.

212) and 26.7 cm (n = 80) CSB snares without diverter wires during the course of their normal wolf trapping in 2005-2006. They neck-caught and killed 20 wolves with the 24.1 cm CSB snare (16 flexible and 4 solid anchors), and 9 wolves (0 escaped) with the 26.7 cm CSB snare (6 flexible and 3 solid anchors). Five of 6 moose (2 calves and 4 adult) caught in the 24.1 cm CSB escaped, and all 3 adults escaped the 26.7 cm CSB snare; captures occurred with 5 flexible and 4 solid anchors. The single moose (yearling female) not escaping was neck-caught (flexible anchor). I assumed that escaped moose were those caught by the leg because the CSB mechanism was not designed to release neck or nose-caught moose. I combined results to test efficiency and selectivity because no wolves, but all leg-caught moose, escaped from both CSB snare types. The CSB breakaway system restrained and killed all 29 wolves and allowed the release of all 8 leg-caught moose; no wolves or moose approached any other available snares. Based on the binomial probabilities (95% confidence level), this breakaway system should kill ≥90% of wolves captured and allow escape of at least 68% of leg-caught moose (Proulx et al. 1994).

DISCUSSION

My data indicate that moose are vulnerable to wolf snares because 1) moose are largely unaware of wolf snares and do not try to avoid them even if detected, 2) the top of the loop of wolf snares is set at a height that corresponds closely to the height at which moose carry their head while walking or sometimes feeding, and 3) even knock-downs mostly retain loop sizes large enough to catch a moose by the leg.

Reducing vulnerability to wolf snares and developing an effective breakaway mechanism is difficult because moose are caught in different manners; most are caught in wolf snares by the nose or leg (Tables 2 and 3). Capture type and rate depend on whether the snare is encountered at its original set height or is a knock-down lying on the trail. I found no difference in catch type or rate due to snare loop size or snow depth. Both nose and leg catches occur at the same proportion if the snare is encountered at original height, but leg-caught moose have to cause a knock-down and step into the loop; I only observed leg catches in knock-downs. Moose are more vulnerable to knock-downs caused by other moose or wind due to the loop size and position on the trail. Not surprisingly, managers and trappers have concentrated on designing snare types more effective in releasing leg-caught ungulates than improving capture selectivity.

I found that moose vulnerability to wolf snares can be reduced by adding a diverter wire that extends from the snare about 70 cm at a 10-20^{o} angle from the horizontal plane tangent to the top of the snare (Fig. 4). The placement and length of this wire ensures that moose will initially contact it instead of the snare, thereby pushing the snare aside or creating a knock-down, and minimizing the chance of a nose/neck-caught moose. Unfortunately, there is no efficient breakaway mechanism that will allow escape of a neck/nose-caught large ungulate. I believe that diverter snares will also minimize neck/nose-caught caribou and other non-target species taller than wolves because the diverter wires would be struck prior to contact with the snare. Importantly, the efficiency of wolf captures was not affected by adding the diverter wire.

Diverter wires did not increase the frequency of knock-downs by wind, but did cause more knock-downs by moose than occurred with standard snares. However, there was no related increased capture of moose suggesting that the diverter snare continued to be effective. My 23 observations of moose contacting diverter snares indicate that the snare usually falls to the trail after contact forming a 15-38 cm loop with the diverter wire maintaining its original orientation. Therefore, subsequent moose on the trail should still contact the diverter wire prior to stepping into the loop. The most likely situations when moose are caught in diverters occur when moose do not follow the trail and bypass the diverter wires, or when diverter wires are damaged. The diverter wires in this study were not damaged after 1-2 knock-downs. All moose caught in diverters were in snares unchecked ≥12 days indicating that the efficacy of diverters may be reduced from repeat contacts with the diverter wire or a moose eventually did not follow the trail. These failures illustrate the need to incorporate a breakaway system to allow leg-caught moose to escape.

I found only one reference evaluating breakaway efficiency for wolf snares (Thompson Snares). Most information describing the efficiency of breakaway snares has come from trappers who report good success with several breakaway mechanisms, particularly the Thompson split lock on 0.24 cm diameter cable and S-hooks (Blejwas 2006). However, there are no reports of trappers or researchers incorporating a cinch stop with any of the breakaway mechanisms on wolf snares. Due to extreme cold temperatures in most of Alaska, moose that do not break free from snares often sustain mortal injuries due to freezing. Therefore, a cinch stop would be a remedial measure for leg-caught moose especially if the snare was anchored to a flexible anchor and more time was required for the moose to break free.

The ideal wolf snare would incorporate a breakaway system that released all leg-caught moose but no neck-caught wolves. The breaking force necessary to cause release of the CSB mechanism placed either at 24.1 or 26.7 cm tested during this study was low enough for all leg-caught moose to break free regardless of the anchor type, but was sufficient to hold all neck-caught wolves. The advantage of the CSB mechanism over other breakaway mechanisms is that it breaks easiest when the lock comes in contact and pushes against the ferrule. Thus the breaking force necessary for release of a leg-caught moose, where the lock contacts the ferrule, will be less than that for a neck-caught wolf where contact is not achieved. The breaking force increases the further the cinch down point is from the CSB mechanism because the force is no longer concentrated on the release, but spread around the entire loop. This is not the case for breakaway mechanisms that are dependent on the lock separating or S-hooks pulling apart; the breaking force is similar for moose and wolves, or possibly less for wolves as loop size is larger (Roy et al. 2005).

Not using a cinch stop can be problematic if the breakaway mechanism does not release the moose because the chance of injury and even death is high due to freezing limbs. To minimize the chance of injury, a cinch stop should be included when S-hooks are the primary breakaway mechanism. Unfortunately, a cinch stop does not work with the split lock on any size cable because a split lock releases when the cable is pulled through the cut. If a cinch stop is incorporated, it would also have to be pulled through the cut. I recommend that trappers use the CSB or S-hooks incorporated with a cinch stop as their primary breakaway mechanisms on wolf snares.

An apparent disadvantage of the CSB was that breaking forces decreased with smaller diameter cable because of less contact surface (less friction) between the cable and ferrule, increasing the possibility that wolves could escape. Some trappers may be reluctant to use the CSB mechanism on 0.24 cm cable using the attachment methods described herein. To alleviate that concern, higher breaking forces can be achieved by increasing the contact surface between the ferrule and cable by increasing the number of times the ferrule is swaged or by using a longer ferrule.

Placement of the CSB on the snare loop is an important consideration because breaking force declines with greater spacing between the CSB and the end stop. I recommend that the CSB be placed at 26.7 cm to minimize the breaking force for moose or other smaller ungulates yet ensure adequate loop size and holding strength to kill wolves. My analysis of loop size relative to cable diameter indicated that this would be adequate for wolf snare cable set 0.24-0.32 cm. For snares using S-hooks as the breakaway mechanism, I recommend placing the cinch stop at 26.7 cm.

Trappers, other researchers (Phillips 1996, Roy et al. 2005), and I have found effective release mechanisms to release ungulates from snares. None of these breaking mechanisms, including the CSB, are efficient in releasing nose-caught moose from wolf snares; the diverter wire is presumably the only mechanism that reduces nose catches.

MANAGEMENT IMPLICATIONS

Snares are an effective method to catch wolves and are a preferred trapping method in Alaska. However, the associated accidental capture of moose is problematic. Based on the characteristics of how moose encounter a wolf snare, I found that incorporating 2 modifications (diverter wire and cinch stop) to the snare resulted in fewer caught and injured moose, and higher escape rate. These changes did not affect the snare's effectiveness to catch wolves as I found no instance where wolves either escaped or evaded capture because the breakaway mechanism released, or by actively avoiding the snare. Both modifications can be easily done by trappers and commercial suppliers of wolf snares on snare cable with 0.24-0.32 cm diameter. Although results are particularly pertinent to wolves and moose, these results are likely applicable in other areas where wolf or coyote snaring occurs in the presence of other large hoofed mammals. Importantly, these modifications will improve selectivity without reducing efficiency of wolf snares.

In areas of high moose density where wolves are trapped intensively, I recommend that a cinch stop be required, and possibly a diverter wire, to reduce the chance of accidentally catching and restraining moose. Furthermore, a maximum 7-day snare check should be considered because knock-downs make moose more vulnerable to capture, albeit, recognizing that trapping in rural Alaska and Canada often requires long trap-lines and severe weather conditions that may require special consideration.

Using captive moose to evaluate vulnerability to snares and test snare modifications proved to be an opportunistic and valuable approach. If possible, further study to improve selectivity and efficiency of snares should be conducted with tractable moose to realize optimal sample sizes and testing design. Specifically, I recommend evaluating the influence of snare loop size by investigating loop sizes <153 cm. I documented no reduced capture rate in 153-cm snare loops as compared to 183-cm loops, despite the top of the tear-dropped shaped loop of 183-cm snares being at least 7.9 cm higher. The ideal loop size would be >153 cm and reduce the chance of caught moose, yet maintain high efficiency in wolf capture.

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