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Tools and Technology

Evaluating Fladry Designs to Improve Utility as a Nonlethal Management Tool to Reduce Livestock Depredation

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ABSTRACT Nonlethal deterrents against carnivores are important components to protecting livestock and conserving carnivore populations. However, the performance of the visual deterrent called fladry, a historical tool used to defend livestock from carnivores, is often hindered by design flaws that eventually reduce its effectiveness. Our purpose was to identify a fladry design that reduces coiling (i.e., wrapping of individual flags tight to the rope from which they hang) and maintains free movement of the deterrent in the wind. We created 6 new designs, replicated designs using 2 materials (nylon and marine vinyl), and compared them with the design most commonly used today—where flags were sewn directly onto the line along which they are strung. We conducted the study during January–February 2014 at the U.S. Department of Agriculture, Wildlife Services, Predator Research Facility in Millville, Utah, USA. Fladry made of marine vinyl and attached via 2 of our 6 designs showed the least amount of coiling, were relatively easy to construct, and did not result in significant additional costs. The 2 designs were shower curtain, where the flags are attached via circular links, and knotted, where a knot is tied in the flag below its point of attachment. We suggest users of nylon fladry modify it to one of these designs and advise new users to consider a heavier (e.g., marine vinyl) material. © 2015 The Wildlife Society.

KEY WORDS carnivore conservation, livestock depredation, nonlethal control, predator management.

Human–carnivore conflict is a major threat to carnivore conservation and ecosystem function (Estes et al. 2011, Ripple et al. 2014). Retaliatory killing of carnivores for livestock depredation is a primary source of human-caused carnivore mortalities (Woodroffe and Ginsberg 1998, Gittleman et al. 2001, Woodroffe et al. 2005) and short-term strategies to alleviate conflict are necessary (Treves et al. 2009).

Nonlethal tools to protect livestock from carnivores mediate conflict and increase tolerance for the presence of wolves (*Canis lupus*) and coyotes (*C. latrans;* Mech 1996, Lance et al. 2010). They can be used independently or in concert with lethal tools. Some nonlethal tools have long histories of use, while others are based on newer technology. For example, the use of livestock guard dogs is a historical nonlethal tool used to reduce livestock depredation by carnivores in Europe, Africa, and North America (Ciucci and Boitani 1998, Hansen and Smith 1999, Gehring et al. 2010, Rust et al. 2013, VerCauteren et al. 2013). Electric fencing and electronic guarding systems that emit sounds, flashing lights, or electric shocks to frighten predators have recently been shown to reduce livestock depredation by felids in Guatemala (Zarco-González and Monroy-Vilchis 2014) and canids in the United States (Lance et al. 2010).

Another method often integrated with the aforementioned approaches, and one requiring fewer logistics, is a simple visual stimulant called fladry. Fladry, which consist of a strand of flags measuring approximately 50 cm long × 10 cm wide that are sewn onto nylon rope at 35–50 cm intervals, was originally used to hunt wolves in Europe (Okarma 1993). Today, it is primarily used to deter wolves and coyotes from crossing barriers, especially livestock pasture boundaries (Musiani and Visalberghi 2001, Musiani et al. 2003, Mettler and Shivik 2007). When the flags are hung just above the ground, their motion in the wind creates a novel, visual stimulus that frightens canids, and can exclude them from the protected area for 60–75 days (Musiani and Visalberghi 2001, Musiani et al. 2003, Mettler and Shivik 2007, Davidson-Nelson and Gehring 2010). However, in strong winds or thick vegetation, users of fladry in western states have reported it to coil, and create gaps in this optical deterrent. Coiling is when a flag wraps itself tightly around the rope to which it is attached. Once a flag coils, it tends to coil repeatedly, leaving gaps through which wolves, and coyotes may pass. Once fladry is crossed by canids, the fear

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and novelty ends and the boundary is repeatedly crossed (Musiani et al. 2003). Thus, identifying a design that reduces the probability that individual flags will coil will enhance the utility of this nonlethal tool. Our objective was to develop and test novel designs of fladry that might resist coiling while providing economically feasible alternatives to the traditional design.

STUDY AREA

The study was conducted during January-February 2014 within a vacant field at the U.S. Department of Agriculture, Wildlife Services, National Wildlife Research Center's Predator Research Facility in Millville, Utah, USA. The grid was located at 41°39′04″N and 111°48′45″W.

MATERIAL AND METHODS

We created 6 novel fladry designs and compared them with the traditional design, which served as our control for utility with regard to coiling (Fig. 1). The 7 designs tested were control, weighted, slit, shower curtain, 2-rope, threaded attachment, and top knot (Table 1). We used 2 materials for each design for 14 total test-flag types. The materials were rip-stop nylon (which is the standard material used to make fladry) and marine vinyl (which is a thicker and heavier material). Material to make a flag using rip-stop nylon weighed approximately 7 g, while material to make a strand of flag using marine vinyl weighed approximately 30 g. Each fladry strand consisted of 10 flags (50 × 10 cm) sewn 50 cm apart on a 6.5-m-long strand of nylon rope 0.2 cm in diameter.

We made 6 replicates of each design in both materials for 84 total strands of fladry. Locations of all strands were randomly assigned within the grid of fladry, with 3 fladry strands of each replicate set north–south, and the other 3 set east–west to mimic fladry installment around all sides of pens in which livestock may be housed. To further replicate field use, we secured each end of a strand to a T-post so that the bottoms of the 10 flags were 7–12 cm from the ground. We checked fladry daily on all but 3 occasions. In those cases, we checked fladry within 48 hours. During each check, we recorded the following data for each flag: percentage intact (0%, 25%, 50%, 75%, or 100%, where 0% is fully coiled and 100% is fully intact), design and material types, and location within strand. We uncoiled all flags after data were recorded each day. We uncoiled flags to determine whether certain designs were more likely to coil repeatedly. To insure flags encountered weather conditions under which they coil, we set a minimum wind criterion based on wind speed descriptions provided in the Beaufort wind-force scale. We recorded data for survival analysis, described below, for 30 days with an average wind speed >1 miles/hour and maximum 2-min burst speed >8 miles/hour. We obtained wind values from a nearby weather station.

To assess the effect of repeated coiling, we first analyzed our data with a linear mixed-effects model, using the lme4 package in R (R Core Team 2012), to determine whether there were differences in the number of times each design was found ≤50% intact. For the mixed model, direction was a fixed effect, strand was a random effect nested within direction, and number of times each flag was found intact was the outcome variable. We verified assumptions of normality and were able to conduct this analysis with the raw data. The tests were performed in R (R Core Team 2012). To determine which fladry designs are least likely to coil at all, we then analyzed our data via survival analysis using the nest model in Program MARK (White and Burnham 1999). Flags were considered to 'die' the first time they were reported as 0%, 25%, or 50% intact. Flags recorded as 75% or 100% intact were considered 'alive' because all or the majority of the flag was still hanging toward the ground and mobile in the wind.

RESULTS

Fladry testing was completed in 47 days, starting on 14 January 2014. Individual flags coiled (i.e., 0%–50% intact rating) between 0 and 27 days. The direction flags faced (E–W or N–S orientation) did not affect the number of times each was found coiled ($\chi^2 = 0.00$, $P = 0.997$) and was removed from further analysis. When controlling for strand, there was a significant difference in the amount of times each design was found ≤50% intact ($F = 248.47$, $P < 0.001$). All marine vinyl designs coiled less than nylon designs based on

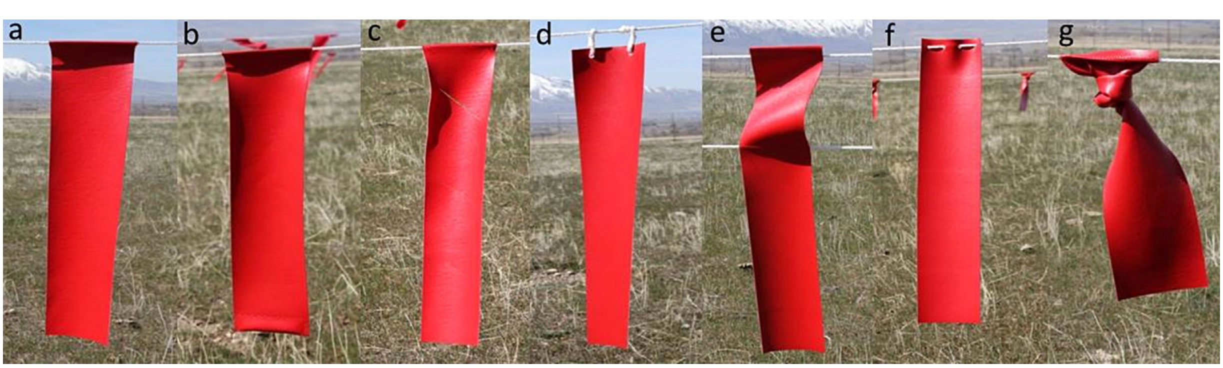

Figure 1. Seven designs of fladry tested during January-February 2014 at the U.S. Department of Agriculture, Wildlife Services, Predator Research Facility in Millville, Utah, USA, to determine which was most likely to remain intact over 30 days. Designs tested were control (a), weighted (b), slit (c), shower curtain (d), 2-rope (e), threaded attachment (f), and top knot (g). All designs shown here are made of marine vinyl but designs were also tested using rip-stop nylon material.

Table 1. Explanation of the 7 fladry designs tested using 2 materials: nylon and marine vinyl. All designs were attached to a thin nylon rope. We conducted the study during January-February 2014 at the U.S. Department of Agriculture, Wildlife Services, Predator Research Facility in Millville, Utah, USA.

Type	Definition
Control (C)	Unaltered original design, stitched tightly to rope.
Weighted (W)	Control stitching at top with a small, split-shot lead fishing sinker sewn into the bottom of each flag.
Slit (S)	Control design with 3 diagonal slits cut into the flags.
Shower curtain (SC)	Attached by threading rope around the strand and through buttonholes sewn into the flags.
2-rope (TR)	Control stitching design but with a second rope sewn 1/3 of the distance down the flag, below the top strand and also tied to the stakes at the ends.
Threaded attachment (TA)	Flag threaded directly onto the rope through 3 buttonholes.
Top knot (TK)	Flags tied just below where they are sewn to the rope.

the average number of flags that coiled each day, but marine vinyl weighted, control, and slit were less consistent and coiled more often than did other designs (Fig. 2a). Nylon control, slit, weighted, and 2-rope coiled more than did other designs (Fig. 2b).

For the 30 days that met our wind speed criteria, all marine vinyl designs had higher survival rates than did nylon designs (Fig. 3). For both materials, the shower-curtain (marine vinyl: $\hat{s} = 0.989$, 95% CI = 0.927–0.999; nylon: $\hat{s} = 0.303$, 95% CI = 0.211–0.416) and top-knot designs (marine vinyl: $\hat{s} = 0.989$, 95% CI = 0.926–0.999; nylon: $\hat{s} = 0.306$, 95% CI = 0.219–0.409) had the highest survival rates, while the marine vinyl weighted ($\hat{s} = 0.584$, 95% CI = 0.480–0.682), and 2-rope nylon design ($\hat{s} = 0.002$, 95% CI = 0.001–0.011) had the poorest survival rates (Fig. 3).

DISCUSSION

Our results provide insight into improving the utility of fladry as a nonlethal predator-control tool. Improving fladry utility may increase the willingness of producers to use it in

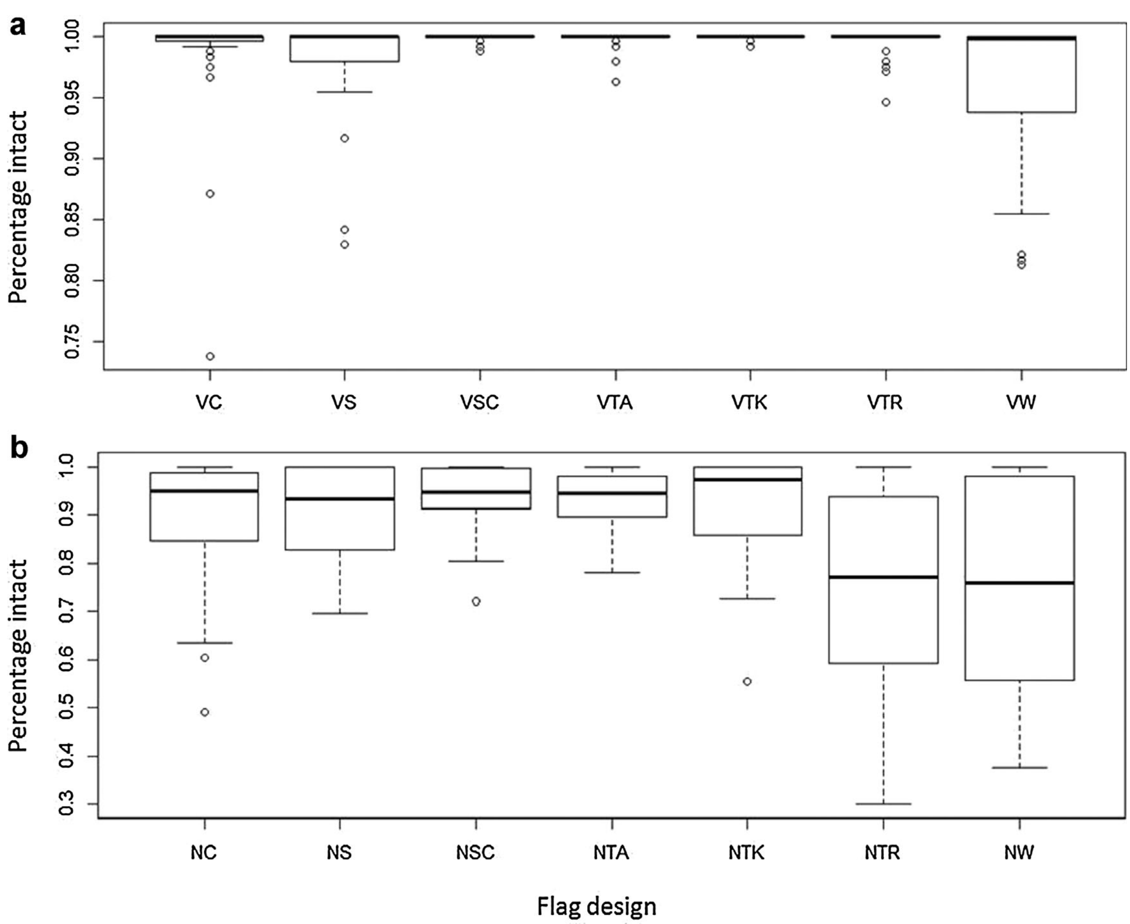

Figure 2. Average daily percentages of flags remaining intact (i.e., uncoiled) and standard error bars for each of 7 designs tested using marine vinyl (a) and nylon (b) materials during January-February 2014 at the U.S. Department of Agriculture, Wildlife Services, Predator Research Facility in Millville, Utah, USA. Flag values are for 47 days of data collection. Note differences in scale of the y-axis. VC or NC: marine vinyl control or nylon control, VS or NS: marine vinyl slit or nylon slit, VSC or NSC: marine vinyl shower-curtain or nylon shower-curtain, VTA or NTA: marine vinyl threaded attachment or nylon threaded attachment, VTK or NTK: marine vinyl top-knot or nylon top-knot, VTR or NTR: marine vinyl 2-rope or nylon 2-rope. VW or NW: marine vinyl weighted or nylon weighted.

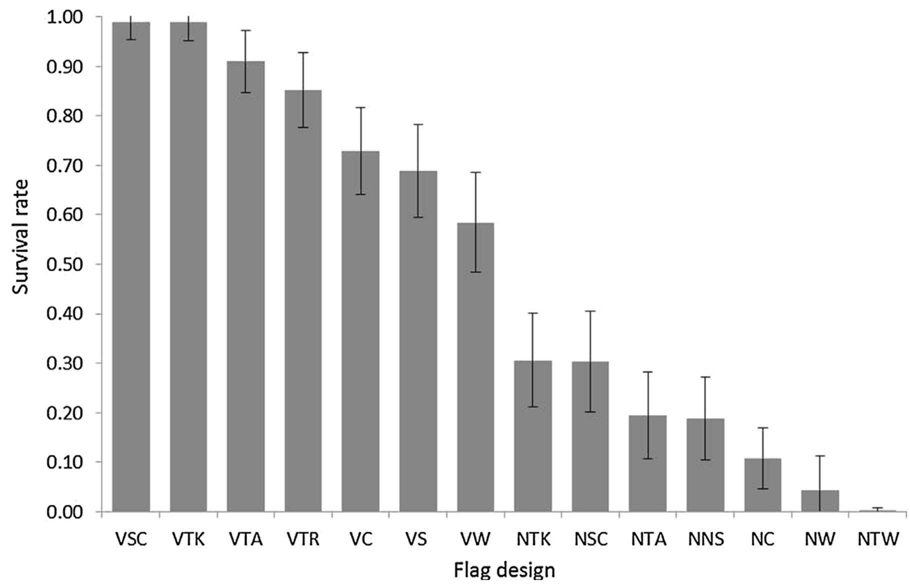

Figure 3. Survival rates and 95% confidence intervals of the 7 fladry designs in marine vinyl (V) and nylon (N) tested over 30 days with wind speed >1 miles/hour (mph) and maximum 2-minute burst speed of 8 mph. We conducted the study during January-February 2014 at the U.S. Department of Agriculture, Wildlife Services, Predator Research Facility in Millville, Utah, USA. See Figure 2 for treatment definitions.

combination with other lethal and nonlethal tools. Nonlethal tools that do not reduce livestock depredation are not only abandoned, but they are typically replaced with lethal options (Cluff and Murray 1995, Treves et al. 2013, McManus et al. 2014). Although lethal removal may alleviate problems at a particular location and time, when used alone it does not offer long-term preventive measures, has higher economic costs over multiple years, and may be unacceptable to the general public (Williams et al. 2002, Nilsen et al. 2007, McManus et al. 2014).

Although most fladry being used in the United States is made of nylon material, we found marine vinyl to be less likely to coil but still light enough to move in a light breeze. The benefits of using marine vinyl are that it is less likely to coil and lasts longer. Marine vinyl was less susceptible to tears and frays from vegetation. We observed that frayed threads became coiled and were less likely to fully uncoil. Although marine vinyl outperformed nylon, it also costs, and weighs more. Raw material costs were US$7.64/m for nylon and US$19.67/m for marine vinyl. Based on the amount of material needed per flag and the spacing of flags, we calculated the cost of fladry to be US$5.88/m for fladry made of nylon, and US$15.13/m for fladry made of marine vinyl. Although marine vinyl is nearly 3 times more expensive, it was also >3 times as likely to remain intact versus nylon during testing. The costs of using both materials were more than the estimate of US$781/km for rip-stop nylon fladry reported in 2006 (Shivik 2006). This may be because of increased costs of materials over time or because we purchased a small amount of material and not in the bulk amount a producer or rancher would likely need. In either case, if these fladry designs are more useful, they remain less costly than shifting to electrified fladry, which costs US $2,302/km (Lance et al. 2010). Weight may not be an issue for ranchers using it on pens that can be accessed by vehicle, all-terrain vehicle, or snowmobile; however, ranchers using fladry in remote areas of public lands may have difficulty carrying large quantities of fladry made of marine vinyl via pack animals or backpacks.

Although our data suggest top-knot and shower-curtain designs were equally likely to remain intact, we suggest using the shower-curtain design with marine vinyl. While observing the fladry over 47 days, we did not see as much movement of flags that were made of the top-knot marine vinyl compared with other designs. This could partially be attributed to the final length of the flag once the knot was added. The marine vinyl top-knot design was approximately 6 cm shorter than the nylon top-knot design because the knot was thicker. Restricted movement of knotted flags may not be as effective at preventing wolves or coyotes from crossing its barrier when compared with the shower-curtain design. Testing both materials in areas with wolves and coyotes is needed to accurately determine whether one design is best.

For current users of nylon fladry, we suggest modifying it to the shower-curtain or top-knot design. These designs stayed intact significantly longer than the traditional fladry design. Changing to these designs will also cost less than purchasing new materials. In general, the top-knot design may be preferable because it can be easily modified from existing fladry and it can be made at home. In fact, some nonprofit agencies in Europe have hosted contests in which school children create fladry from household fabrics using a knot-tying design. The shower-curtain design was more challenging to create, but neither design was extremely complex or time consuming. Testing both designs in field settings, where wild coyotes, and wolves will encounter them, would help determine which design performs better than the other.

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