Original Article

Injury Scores and Spatial Responses of Wolves Following Capture: Cable Restraints Versus Foothold Traps

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ABSTRACT Wolves (*Canis lupus*) have been captured with foothold traps for several decades to equip them with radiocollars for population monitoring. However, trapping in most areas is limited to spring, summer, and autumn as cold winter temperatures can lead to frozen appendages in trapped animals. In addition, conflicts arise when domestic dogs encounter these traps in nonwinter seasons. An alternative capture method is the use of cable restraint devices (modified neck snares) in the winter. We evaluated injury scores, movement patterns, and space use of wolves captured in cable restraint devices and foothold traps in north-central Minnesota, USA, during 2012–2016. Injury scores did not differ between capture techniques; however, movement patterns and space use were different. We found that the movement away from the capture site appeared to plateau by approximately 8–10 days for wolves captured by either foothold traps or cable restraints, but wolves captured in traps travelled farther away. Daily movement rates reached an asymptote approximately 14 days earlier for wolves captured with cable restraints as compared with wolves caught with foothold traps. We found the space use among wolves caught with cable restraint devices plateaued in a shorter time frame than wolves caught with foothold traps whether using days since capture (38 days earlier) or number of locations (149 locations earlier). When we controlled for seasonal effects and the presence of a capture using locational data collected 6 months later, there was no difference in space use. We concluded that wolves captured in cable restraints recovered more quickly from the capture and resumed space use and activity patterns more rapidly than wolves captured with foothold traps. Published 2019. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS cable restraint, *Canis lupus*, foothold trap, home range, injury, movement, wolf.

Trapping of furbearers has been a part of North American culture since before the establishment of the United States (Wright 1987). The colonization and subsequent migration of Europeans to North America facilitated the fur trade with an increased demand for food and fur (Ray 1987). In addition to trapping animals for fur or food, trapping was used as a management tool to reduce property damage and livestock depredations. As early as 1885, the U.S. Department of Agriculture recognized that many species of wildlife needed managing (Krausman 2002). By 1933, mammalian wildlife management came into focus when Aldo Leopold formalized wildlife management with his book *Game Management* (Leopold 1933). Leopold understood that hunting, and by extension, trapping, could be an effective tool to manage furbearer populations and proposed integrating trapping with the science of harvest management. In the mid-1950s, wildlife managers realized trapping and fitting wild furbearers with very-high-frequency radiocollars could provide valuable information on population dynamics, behavior, habitat selection, spatial arrangement of individuals, and even physiology (Anderka 1987). Thus, trapping

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evolved to have an additional objective, that of a research tool to live-capture and mark animals (i.e., ear-tagged or radiocollared) to facilitate monitoring for management and research.

Public attitudes toward trapping are often negative (Gentile 1987, Proulx and Barrett 1991, Richards and Krannich 1991); therefore, new methods were developed to reduce injury or conversely, quicken death (Kuehn et al. 1986, Novak 1987). Modifications included placing pads on the jaws of foothold traps (e.g., Linhart 1983, Olsen et al. 1986, Linscombe and Wright 1988, Frame and Meier 2007), development of "breakaway" devices on neck snares or cable restraints, devices to reduce nontarget captures (Short et al. 2012), and attachment of tranquilizer tabs to reduce injuries (Sahr and Knowlton 2000). Concomitant with new trap development was the need to assess injuries from traps; thus, a standardized set of injury scores was developed facilitating comparison among different trap types, trapping schemes, and visitation schedules. Van Ballenberghe (1984) introduced a rank-based scoring system that assigned injuries into 4 classes: no injury (class I), moderate injury (class II), or severe injuries (classes III and IV). Fleming et al. (1998) added a fifth class, death, to the Van Ballenberghe (1984) scoring system. Additionally, Tuller (1984) developed a quantitative scoring system allowing for statistical evaluations upon which Olsen et al. (1986) expanded. The Olsen scoring system facilitated statistical comparison of trap injuries by having a minimum of zero for no injury to a maximum of 400 for amputation of a limb, but no score for death. Onderka et al. (1990) expanded on Olsen's scores by incorporating bone fractures and loss of digits and assigning those injuries intermediate injury scores, but also did not include a score for death. Eventually, there was a need for wildlife agencies to develop standards for testing traps according to the International Organization for Standardization (International Organization for Standardization 1999), which produced the Best Management Practices framework for evaluating traps (Association of Fish and Wildlife Agencies 2006). International trade in furbearers eventually led to adoption of these testing standards for traps used on land to restrain mammals. The performance testing includes methods for evaluation of trauma, selectivity, capture efficiency, and user safety (International Organization for Standardization 1999).

In addition to physical injuries, animals may exhibit behavioral responses to capture such as reduced movement rates, changes in home-range size, avoidance of the habitat in which they were trapped, or even permanent dispersal or displacement from the capture site. In general, bears (*Ursus* spp.) may exhibit reduced movements following capture, as indicated by polar bears (*U. maritimus*; Cattet et al. 2008, Rode et al. 2014) and brown bears (*U. arctos*; Støen et al. 2010), but return to normal movement rates within 2–3 days (Thiemann et al. 2013, Rode et al. 2014). Cougars (*Puma concolor*) in southcentral New Mexico, USA, remained closer to capture locations during the first 3 days postcapture compared with $\geq$4 days postcapture (Logan et al. 1999). Theoretically, the physical stress of capture could influence what habitat is perceived as threatening, and result in changes in home range use. Roe deer (*Capreolus capreolus*) were located further from the center of their home range following capture and their displacement increased with the openness of the habitat (Morellet et al. 2009). Amphibians have also abandoned home ranges or undergone temporary emigration from capture sites (Germano 2007, Price et al. 2012). Although Eurasian lynx (*Lynx lynx*) in Norway did not switch habitats following foot-snare capture, they did take longer to return to the capture site than a random point (Moa et al. 2001).

There is a long history of using foothold traps for capturing and radiocollaring wolves (*Canis lupus*) for research and population monitoring (e.g., Mech 1977, Fritts and Mech 1981, Fuller 1989). A concern among researchers is avoiding capture of nontarget animals during trapping operations, particularly domestic dogs. Most foothold trapping for research is conducted in the summer and autumn in areas frequented by the public and their dogs. Furthermore, using foothold traps for live-capture in winter is typically not recommended because of the risk of tissue freezing from reduced circulation in the restrained appendage. Finally, there are seasonal, geographic, and temporal selectivity considerations for all capture devices. Use of cable restraints during winter may yield high selectivity due to limited opportunity of capturing bears while hibernating; low likelihood of capturing smaller carnivores due to wolf-specific loop size, placement, and loop stops; and the ability to incorporate release mechanisms for ungulates. Using cable restraints for capturing wolves in the winter is viewed as an additional or alternative capture method that could expand live-capture opportunities with minimal concerns. However, there is no information on the effects of cable restraints on injury rates and subsequent movement of wolves. In fact, in canids only anecdotal evidence exists that suggests the type of trap can influence behavioral responses of coyotes (*C. latrans*). Although one Global Positioning System (GPS)-collared coyote in Michigan, USA, trapped in a cable restraint (neck) snare had a smaller home range than coyotes trapped in prior years with foothold traps, a second GPS-collared coyote had a similar home-range size compared with foothold-captured coyotes (Wegan et al. 2014). Thus, changing from the traditional foothold traps to neck cable restraints for wolf captures necessitated an evaluation of the 2 techniques. We investigated the utility of cable restraints versus foothold traps for capturing wolves for research purposes by determining if injuries, movement patterns, and space use were different for wolves live-captured in foothold traps during summer versus wolves captured in cable-restraint neck snares during winter in north-central Minnesota, USA.

STUDY AREA

The study area covered several counties in north-central Minnesota. The largest city centrally located in the study area was Grand Rapids. Topography was rolling hills interspersed with many lakes. Mixed coniferous–hardwood forests and prairie parklands dominated the area with conifers, hardwoods, bogs, and swamps characterizing mixed forests (Hanberry et al. 2012), while grasses and shrubs characterized the parklands (Minnesota Department of Natural Resources, www.dnr.state.mn.us/ecs/212/index.html, accessed May 2017). For Grand Rapids, average January high and low temperatures were −7.0 and −19.3° C, respectively; average July high and low temperatures were 26.8° and 13.3° C, respectively. Mean annual rainfall was 72.3 cm in the spring, summer, and autumn. Mean annual snowfall was 142.5 cm, with snow present from late November into April (U.S. Climate Data, usclimatedata.com/climate/grand-rapids/minnesota/united-states/usmn0309, accessed Aug 2017).

METHODS

Wolf packs in north-central Minnesota have been extensively monitored since the late 1970s with the goal to maintain ≥1 radiocollared individual in each pack under study. To maintain consistency with past monitoring, we focused trapping efforts in areas without monitored wolves present, such as where a radiocollared wolf had died, dispersed, or a radiocollar battery died or the collar malfunctioned and was not sending a signal. We set traps in areas with active wolf sign, lower risk of human disturbance, and available road or trail access. Although trapping occurred within the study area prior to and following this study, we only examined wolves trapped and snared during 2012–2016. We used cable (neck) restraints (Rally Hess Enterprises, Hill City, MN, USA) to capture wolves only in winter months (Dec through Mar). Cable restraints were constructed using 2.5–3 m of 3-mm 7 × 7 cable with a reverse-bend washer lock. Restraints were equipped with a #12 in-line barrel swivel rated at 1,500 lbs (680 kg) and a "loop stop" affixed approximately 40 cm from the terminal end of the cable, resulting in a minimum potential loop diameter of approximately 12 cm. We anchored cable restraints at ground level using an "earth anchor" away from potential features of entanglement (i.e., trees and brush >3-cm diameter). Although static load testing on a sample of 10 of the original restraints resulted in loop stops slipping at an average of 732 lbs (332 kg) of force, one wolf died because of loop stop failure. After this mortality, all future cables were equipped with longer loop stops, which static load testing suggested could sustain a minimum of 1,000 lbs (454 kg) of force; no mortalities occurred thereafter. We set foothold traps (#4 offset jaw, #4 EZ grip padded jaw, or #7 EZ Grip; Livestock Protection Company, Alpine, TX, USA) in summer and autumn (Jun through Oct). Capture procedures were according to Minnesota Department of Natural Resources protocols and followed protocols used during the Association of Fish and Wildlife Agencies development of Best Management Practices for trapping. We checked all traps and snares daily in the morning.

Upon capture, we immobilized wolves with a mixture of ketamine hydrochloride and xylazine (Fuller and Kuehn 1983), and recorded measurements including sex, mass, chest, head, and neck girth, and assessed for injuries (e.g., cuts, abrasions, foot, and tooth injuries). We fitted wolves with a GPS radiocollar (either Lotek, Newmarket, Ontario, Canada; or Followit, Lindesberg, Sweden) and a numbered ear tag. The GPS collars acquired locations at variable intervals, but generally were a minimum of 30 minute to a maximum of 6 hours apart. We monitored rectal body temperature until we administered the reversal agent (yohimbine hydrochloride) and a dual-acting antibiotic. Processing time generally took 1–2 hours depending on the individual wolf's reaction to the immobilization drugs and reversal agent.

We used the trauma scale adopted by the International Organization of Standardization (IOS) to evaluate injuries sustained by wolves captured in the 2 devices (International Organization for Standardization 1999). Some trauma scores would require pathological examination (i.e., postmortem examination), so not all scores listed in the trauma scale pertained to live-captured animals. In addition, the IOS trauma scores did not include minor injuries to the mouth; thus, we added scores for a chipped tooth (5 points), minor mouth or gum bleeding (5 points), and oral laceration <2 cm long (5 points). We compared mean injury scores between the 2 capture devices with a Student's *t*-test (Zar 1996).

Results of capture, either injury or immobilization, may manifest themselves in restricted movement or activity following release (Wegan et al. 2014). To assess whether the type of device influenced movement and activity of wolves following capture, we examined 4 movement metrics including a) the distance moved away from the capture location following release; b) the movement rate or speed of travel following release; c) the area of use as a function of days following release; and d) the area of use as a function of the number of GPS locations acquired following release.

Injuries sustained during capture may limit animal mobility and thus constrain the individual to remaining near the site of capture. Therefore, for the first movement metric, we calculated the mean daily distance between the capture location and each GPS-collar location for each day up to 103 days posttrapping. We used all GPS locations collected for the subsequent 103 days following capture because we believed seasonal changes in landscape use may confound our results beyond this 3.5-month timeframe. We averaged the distance between the animal and capture location across entire days rather than by the time of day because we did not know the precise time each wolf left the capture site. We conducted generalized linear mixed models (GLMM), with wolfID as the random effect, with the response being the mean distance between the capture site and all the locations in that day, and the independent variables of number of days postcapture and capture device. We constructed 4 possible models: number of days postcapture, capture device, number of days postcapture + capture device, and number of days postcapture × capture device.

For the second movement metric, we calculated the hourly mean movement rate for each day posttrapping by measuring the distance moved between successive locations collected every 4 hours for most wolves and every 6 hours for 1 cable-restrained wolf. For this second metric, we conducted

GLMMs, with wolfID as the random effect, with the response being the mean movement rate (standardized to m/hr), and the independent variables of number of days postcapture and capture device. We constructed 4 possible models: number of days postcapture, capture device, number of days postcapture + capture device, and number of days postcapture × capture device.

For the third movement metric, we determined the area of use (defined as the outer boundary of the 95% minimum convex polygon) for each wolf as delineated by GPS locations. The short time intervals immediately after capture (i.e., 3, 6, 9 days, etc.) may not represent a home range; thus, we considered these areas as areas of use. We calculated the cumulative area of use by adding 3 days of locations at each time point; similar to an area-observation curve (Odum and Kuenzler 1955). For the final movement metric, we similarly calculated the 95% minimum convex polygon for area of use, adding 5 locations at each time point to determine the cumulative area of use—again, similar to an area-observation curve. For the third and fourth metrics, we used area-observation curves to determine the time (either no. of days or no. of locations) at which an asymptote was reached for each wolf; similar to the methods of Fuller and Snow (1988), and Gese et al. (1990). The asymptote was determined as the point at which any additional locations did not increase the area of use by >10% of the total home-range size; this generally occurred at approximately 91–94% of the total home-range size. We compared the time of the asymptote between the 2 capture devices using a Student's *t*-test (Zar 1996). The prediction of all these spatial metrics was that injuries involving the feet or legs were more likely to, at least temporally, limit mobility and wolves would restrict their movements and take longer to resume normal activity levels and space use.

We recognized that wolves captured with cable restraints were always in winter and foothold trapping was only in the summer and autumn and, therefore, seasonal changes in wolf behavior could influence differences in space use. Thus, to determine whether there was a seasonal influence on space use, we used locational data from the same radiocollared wolves, but offset by 6 months. That is, we determined the same spatial area-observation curves described above, but with locations from the cable-restraint animals in the summer and locations from the foothold-trapped wolves in the winter, thereby comparing these cohorts without a capture influencing their movement patterns and in the opposite season. We then compared the time of the asymptote between the 2 capture devices using a Student's *t*-test (Zar 1996). We determined all spatial information in ArcGIS 10.2.2 (ESRI, Redlands, CA, USA) and conducted all statistical analyses in R (R Core Development Team 2017).

RESULTS

We captured and evaluated injuries of 23 wolves captured in foothold traps and 24 wolves captured with cable restraints. With the exception of a single death in a cable restraint due to mechanical failure, there were no severe injuries in the 23 wolves captured in foothold traps or in 23 of the wolves captured in cable restraints. Using the International Organization of Standardization trauma scale to evaluate injuries, the mean injury score for wolves captured in cable restraints was 19.6 ± 24.2 (standard deviation: SD) with the single death included and 15.9 ± 17.1 if the single death is excluded, while the mean injury score for wolves captured in foothold traps was 15.0 ± 22.9. The large SDs were due to the large individual variation in injury scores, with 50% of the captured wolves having no or low injury scores (0–5 points) while 28% of the wolves had scores of 30-60 points, for both capture devices combined. There was no difference between the injury scores for foothold traps versus cable restraints with ($t_{44} = 0.66$, $P = 0.26$) and without ($t_{43} = 0.15$, $P = 0.44$) the death of the one wolf in a cable restraint device. Although the mean injury scores did not differ between the 2 capture devices, injury locations on the wolves were, as expected, vastly different. Frequency of injuries to the feet and legs (e.g., lacerations, punctures, lost toes) among wolves captured in foothold traps was 60.8%, while only 4.5% of snared wolves had injuries to their feet and legs ($\chi^2_1 = 16.72$, $P < 0.001$). In contrast, 26.1% of the wolves captured in foothold traps had injuries to their mouths (e.g., cut lips, lost teeth), while 77.3% of the snared wolves had injuries to their mouths ($\chi^2_1 = 12.54$, $P < 0.001$). However, actual tooth damage (chipped or broken teeth) was less when using the pliable cable restraints (0% of captured wolves) compared with wolves captured with steel foothold traps (21.7%); most of the oral injuries among wolves captured with the cable restraints was to the gums, tongue, and lips.

Twenty-two wolves captured in cable restraints and 23 in foothold traps were equipped with GPS collars to examine the distance travelled from the capture site and movement rates; 2 wolves captured in cable restraints were not included because they were not radiocollared. For the first movement metric, 100% of the model weight for the distance travelled from the capture site was explained by 2 models (Table 1). By

Table 1. Generalized linear mixed models, with WolfID as a random effect, with the response variables of a) mean distance travelled from the capture site, and b) the mean movement rate, as a function of the independent variables of capture device and the number of days postcapture, for wolves in north-central Minnesota, USA, 2012–2016. Only models with a weight ≥0.10 are included.

Analysis	Model	ΔBIC[a]	Weight
Distance from capture site	Number of days + Device	0.0	0.72
	Number of days × Device	1.8	0.28
Movement rate	Number of days	0.0	0.55
	Number of days × Device	0.5	0.43

[a] BIC = Bayesian information criterion.

approximately 8–10 days postcapture, wolves captured by both techniques exhibited an asymptote (i.e., slopes of the curve were declining) in distance moved from their capture site, but wolves captured in foothold traps moved further away from the capture site as time went on (Fig. 1). The mean distance moved between the capture site and GPS collar locations was slightly lower for cable restraint-captured wolves (8.1 ± 0.18 km, standard error: SE) than foothold-captured wolves (9.9 km ± 0.17 km). As the number of days postcapture increased, the distance moved increased in a logarithmic fashion for cable restraint- and foothold-captured wolves, although the foothold-captured wolves moved consistently farther away from the capture site than cable-restrained wolves (Fig. 1).

For the second movement metric, 98% of the model weight for the mean daily movement rate was explained by the number of days since capture and capture device (Table 1). In general, wolves captured in cable restraints exhibited greater movement rates in the days immediately following capture compared with foothold-captured wolves (Fig. 2). For the wolves captured using cable restraints, their movement rate reached an asymptote within 5–7 days, whereas wolves captured with foothold traps did not reach an asymptote until approximately 20–24 days. The maximum movement rate for cable restraint–captured wolves was 511 m/hour on day 77 and for foothold-trapped wolves, 441 m/hour on day 100. The average movement rate for cable-restrained wolves and foothold-trapped wolves was 342 m/hour and 278 m/hour, respectively; although the standard error (6.8 m/hr) was larger for the foothold-trapped wolves than for cable-restrained wolves (5.8 m/hr). The relationship between movement rates and number of days postcapture was weaker for cable restraint–captured wolves than for foothold-trapped wolves (Fig. 2).

For the final 2 metrics, 4 wolves captured in cable restraint devices and 3 wolves captured with foothold traps were not included in the analyses of space use because 1 wolf was not monitored long enough (8 days) and the other 6 animals were determined to be transient or dispersing wolves with areas of use $>500\,km^2$. There was a high degree of individual variation in the estimates of area of use among all captured wolves. Wolves captured in the cable restraint device showed an asymptote in their area-observation curves after an average of 40.7 days (SD = 27.1 days), while wolves captured in foothold traps showed an asymptote after an average of 79.2 days (SD = 22.4 days). This 38 days differed ($t_{36} = 4.80$, $P < 0.001$) between the 2 capture devices. As the number of days postcapture increased, the mean cumulative area of use increased with the greatest slope exhibited during the first 15 days postcapture (Fig. 3), after which the rate of increase decreased with cable restraint–captured wolves showing an asymptote in their area of use, on average, by 41 days; whereas, foothold-trapped wolves lagged behind and did not indicate an asymptote until an average of 79 days post-capture. However, both area-observation curves did eventually meet, showing that overall space use was similar for wolves captured by both methods, but a longer time lag before use of their full area for the foothold-trapped wolves (Fig. 3). The asymptote exhibited for the cable restraint–captured wolves suggests these areas of use likely reflected the home-range or territory size. The area of use curves exhibited strong (both $r^2 > 0.80$) logarithmic increases for wolves captured in both foothold traps and cable restraints. In contrast, the area-observation curves constructed from locations 6 months after capture (Fig. 4) showed wolves captured in cable restraints reached an asymptote on average in 55.5 days (SD = 27.6 days) and wolves captured in foothold traps reached an asymptote on average in 48.4 days

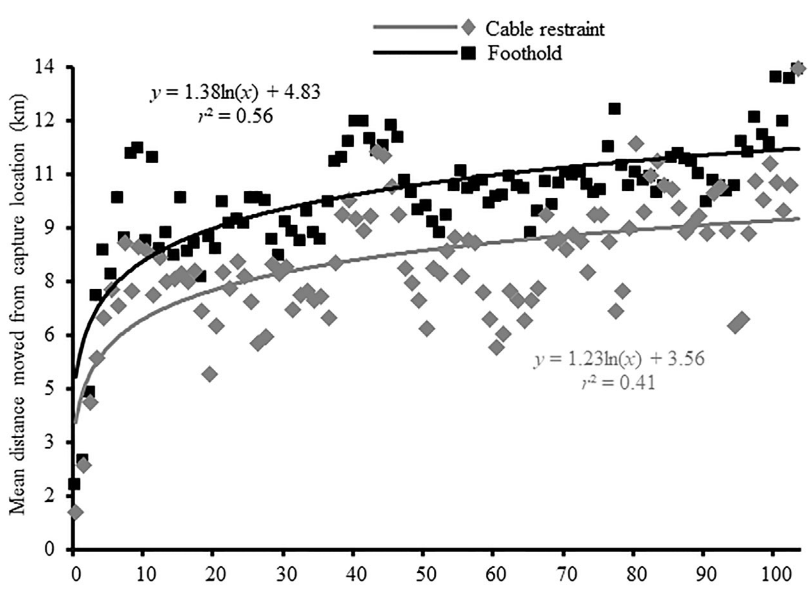

Figure 1. Mean distance (m) between each wolves' capture site and subsequent daily Global Positioning System locations following capture for wolves captured with cable restraints versus foothold traps monitored for up to 103 days postcapture, north-central Minnesota, USA, 2012–2016.

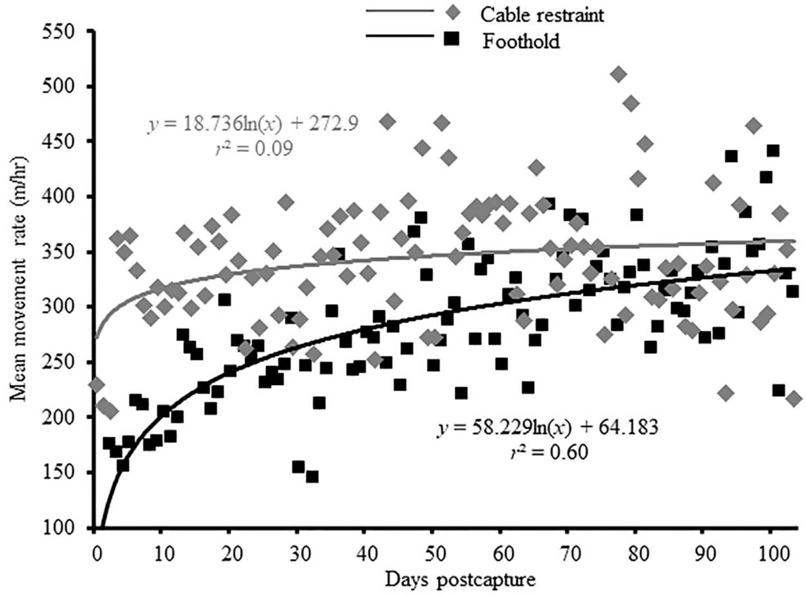

Figure 2. Mean daily movement rate (m/hr) between Global Positioning System locations following capture for wolves captured with cable restraints versus foothold traps monitored for up to 103 days postcapture, north-central Minnesota, USA, 2012–2016.

(SD = 18.6 days). There was no significant difference between the 2 capture devices in the time to reach an asymptote after 6 months following capture ($t_{17} = -0.67$, $P = 0.26$).

For our final movement metric, we determined the cumulative area of use as a function of the number of GPS locations, similar to the previous metric but using locations rather than days. Again, there was a high degree of individual variation among the wolves in area of use following capture. Similar to the previous metric, wolves captured with cable restraints reached an asymptote on average by 280.0 locations (SD = 165.8 locations), whereas wolves captured with foothold traps did not reach an asymptote in area of use until 429.3 locations (SD = 120.6 locations). This difference of 149 locations was significant ($t_{36} = 3.07$, $P = 0.002$) between the 2 capture devices. However, similar to the previous metric, the home-range size curves do eventually meet, but the foothold trap curve showed an obvious time-lag in recovery (Fig. 5). The decline in the area of use after 450 locations among wolves captured with cable restraints was due to the loss of several animals attributable to livestock depredations. Similar to the previous

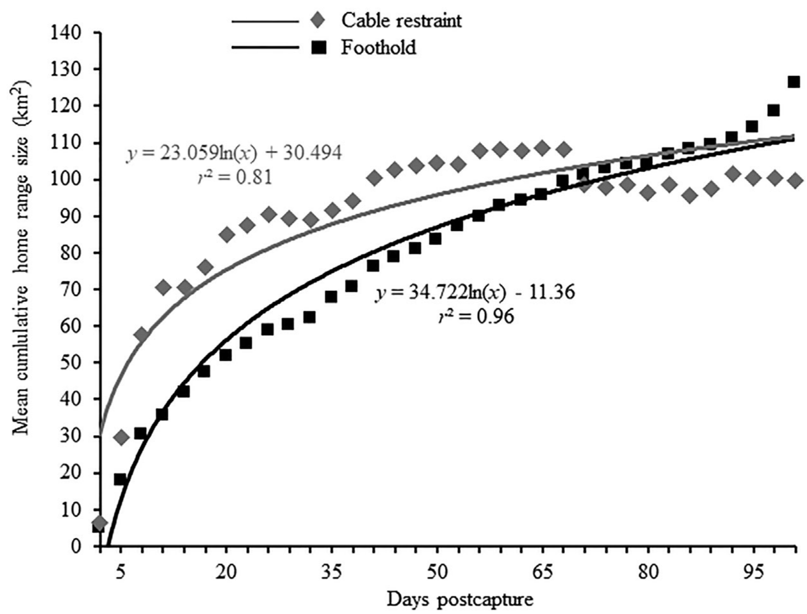

Figure 3. Mean cumulative area of use (home-range size) as a function of days postcapture for Global Positioning System–collared wolves captured with cable restraints and foothold traps, north-central Minnesota, USA, 2012–2016.

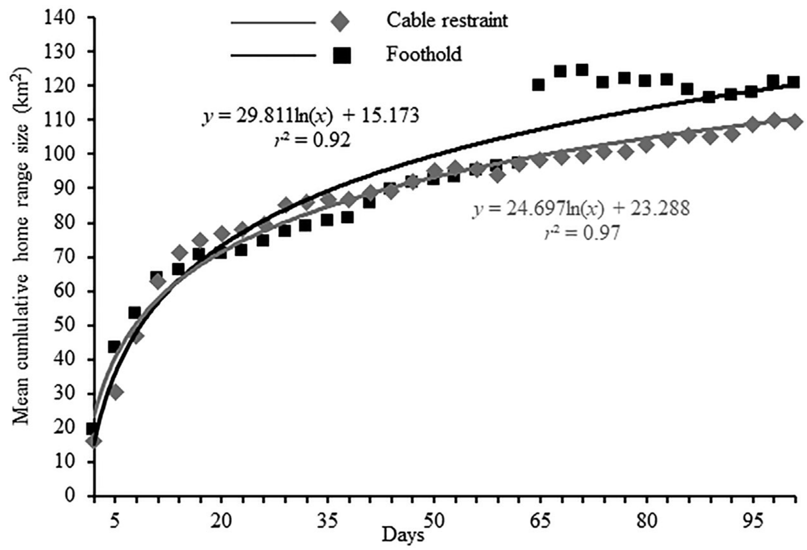

Figure 4. Mean cumulative area of use (home-range size) as a function of days for Global Positioning System–collared wolves, 6 months after being captured with cable restraints and foothold traps, north-central Minnesota, USA, 2012–2016.

metric, when we constructed area-observation curves using locations collected 6 months after capture (Fig. 6), wolves captured in cable restraints and foothold traps reached asymptotes on average by 292.7 locations (SD = 69.1 locations) and 276.8 locations (SD = 85.7 locations), respectively ($t_{17} = -0.40$, $P = 0.35$). We concluded that differences in the time lags to resume normal space use following capture was due to the capture devices, not to seasonal differences in space use.

Space use could be confounded by the severity of the injuries. Therefore, we also constructed area-observation curves for this final movement metric by further dividing the wolves captured by both devices into 2 injury score classes: 1) no to low injury scores (0-15 points), and 2) moderate to high injury scores (>25 points; range 25 to 100). We found the injury score for the capture devices influenced the time span in which the wolf resumed normal space use (Fig. 7). Wolves captured with cable restraints and having no or low injury scores resumed normal space use the fastest, followed by wolves captured with foothold traps and having no or low injury scores, then lastly, both cohorts having moderate to high injury scores showed the longest delay in resuming normal space use (Fig. 7). Within the no to low injury score class, the area-observation curves showed wolves captured with cable restraints reached an asymptote by 232 locations (SD = 165 locations, $n = 11$) which differed ($t_{24} = 3.49$, $P = 0.0009$) from wolves captured with foothold traps which reached an asymptote by 436 locations (SD = 132 locations,

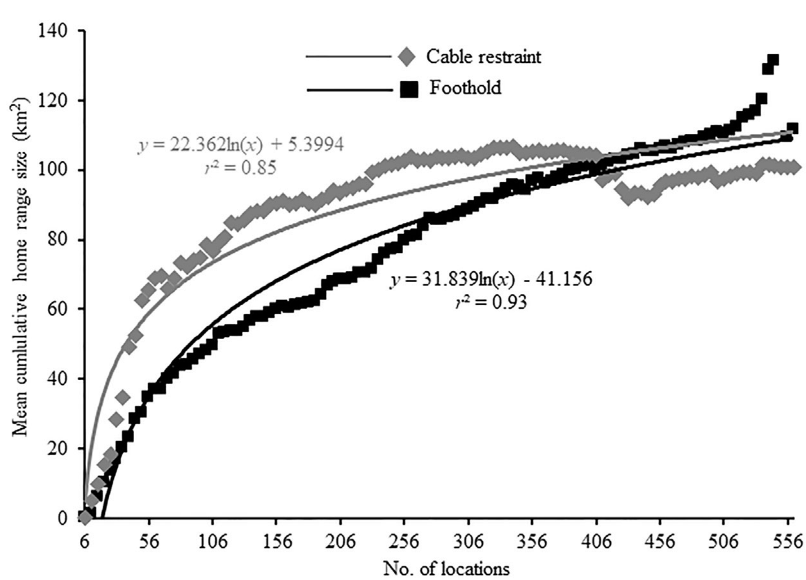

Figure 5. Mean cumulative area of use (home-range size) as a function of the number of locations postcapture for Global Positioning System–collared wolves captured with cable restraints and foothold traps, north-central Minnesota, USA, 2012–2016.

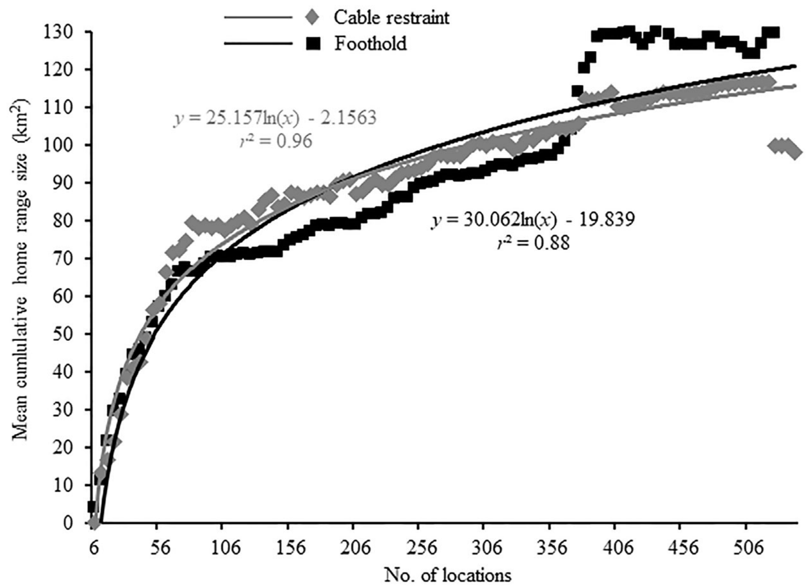

Figure 6. Mean cumulative area of use (home-range size) as a function of locations for Global Positioning System–collared wolves, 6 months after being captured with cable restraints and foothold traps, north-central Minnesota, USA, 2012–2016.

$n = 15$). Within the moderate to high injury score class, wolves captured with cable restraints reached an asymptote by 371 locations (SD = 136 locations, $n = 7$), which did not differ ($t_{10} = 0.56$, $P = 0.29$) from wolves captured with foothold traps which reached an asymptote by 410 locations (SD = 85 locations, $n = 5$).

DISCUSSION

A comparison of capture effects between traditional foothold trap and cable restraint devices was valuable to assist with decisions related to continued monitoring of wolves in Minnesota. We found that although injury scores did not differ between the 2 capture techniques, movement patterns and space use indicated a behavioral and spatial difference in response to these 2 capture techniques. We found that the movement away from the capture site appeared to begin to plateau by approximately 8–10 days for wolves captured by either foothold traps or cable restraints. However, distance moved from the capture site was much farther for wolves captured with foothold traps. Daily movement rates reached

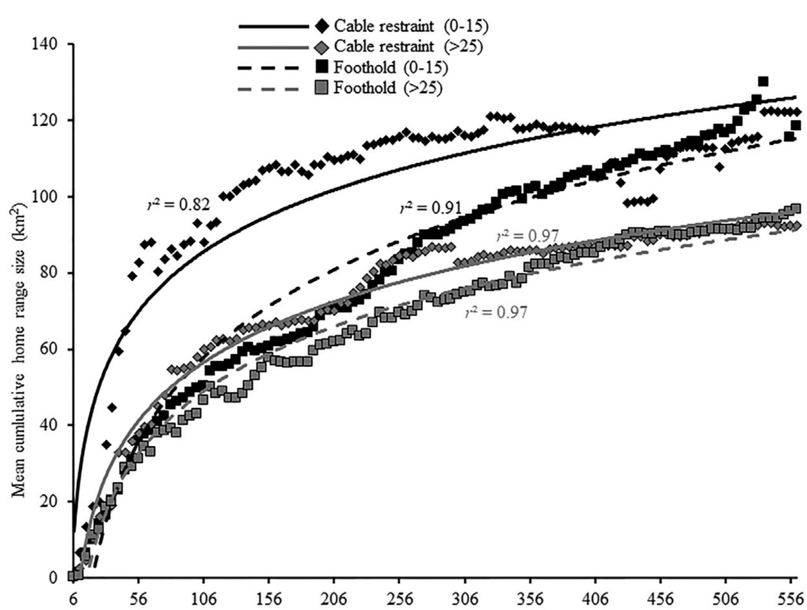

Figure 7. Mean cumulative area of use (home-range size) as a function of the number of locations postcapture for Global Positioning System–collared wolves, captured with cable restraints and foothold traps, divided into 2 injury score classes (0-15 points; >25 points), north-central Minnesota, USA, 2012–2016.

an asymptote much earlier for animals captured with cable restraints compared with wolves caught with foothold traps. Finally, space use or area of use among wolves caught with cable restraint devices plateaued in a shorter timeframe than animals caught with foothold traps, whether using days since capture or number of locations. When we controlled for season and the presence of a capture using locational data collected 6 months after the capture, we found no differences in space use between animals captured in cable restraints and foothold traps. Thus, we concluded that wolves captured in the cable restraints recovered more quickly from their capture and had resumed space use and activity patterns more rapidly than did wolves captured with foothold traps. This difference in space use and activity was likely due to injuries principally to the feet and legs among wolves captured in foothold traps, which thereby temporarily hindered movement. However, should foothold traps be the only method for capturing wolves, use of trap tranquilizer devices (TTDs) can significantly reduce injuries (Sahr and Knowlton 2000).

As indicated by the faster resumption of space use for wolves captured in cable restraints with no to low injury scores versus foothold-trapped wolves with no to low injury scores, there were likely subcutaneous injuries from capture in the foothold traps that go undetected with only a gross examination of external injuries at the time of capture. Postmortem examinations by veterinary pathologists of legs from trapped animals often showed edematous swelling or hemorrhage, subcutaneous tissue maceration or erosion, and tendon or ligament severance (Phillips et al. 1996, Shivik et al. 2005), which are types of injuries not generally ascertained without performing a postmortem examination. In contrast, wolves captured with cable restraints suffered more injury to their mouth, but these wounds would not hinder movement, although they could influence predation and feeding.

Oral injuries to wolves in our study were more common from cable restraints than foothold traps, similar to other studies (Onderka et al. 1990, Fleming et al. 1998, Wegan et al. 2014); 77% of the wolves experienced oral injuries, but only 26% of the foothold-trapped wolves had oral injuries. However, actual tooth damage (chipped or broken teeth) was less when using the pliable cable restraints (0% of captured wolves) compared with the incidence of tooth damage to wolves captured with foothold traps (21.7%). Although animals sustain fewer injuries and have a reduced chance of having frostbitten toes and appendages in winter with cable restraints (Mowat et al. 1994), risk of death may be more likely with cable restraints than with foothold traps, though the risk appears to be low or preventable stemming from mechanical failures or poor deployment locations (e.g., too much entanglement), with some risk associated with unplanned catch locations on the body that negate effects of the loop stop (e.g., this study; Shivik et al. 2005; Muñoz-Igualada et al. 2008, 2010; Etter and Belant 2011).

Even though cable restraints resulted in fewer injuries to coyotes, Onderka et al. (1990) reported that the capture rate was dependent on the correct placement on the landscape and use of the correct type of snare for the species of interest. In addition, Skinner and Todd (1990) reported lower trapping efficacy for cable restraints compared with foothold traps for coyotes, dingos (*C. lupus dingo*), foxes (*V. vulpes*), domestic dogs (*C. lupus familiaris*), and in isolated instances, feral cats (*Felis catus*) in Australia, but overall resulted in fewer injuries than any of the foothold traps (Fleming et al. 1998). Although trappers in our study reported successes with both capture devices, we did not document overall efficacy of the 2 capture devices because our objective was strictly focused on determining injury rates and spatial responses.

Other studies have also documented the effects of capture on carnivores. An adult male cougar that lost a toe in a foothold trap stayed within 540 m of the capture site for 3 days and then moved >1 km on the fourth day, whereas a severely injured juvenile female cougar stayed <450 m from the capture site for 6 days and joined its mother on day 7 (Logan et al. 1999). Although the 2 cougars suffered serious injuries, they were not life threatening and suggest cougars are affected by foothold trapping for a relatively short time. Greater than half of the polar bears captured by remote injection from a helicopter moved short distances during the 12 hours postrelease and returned to normal movement rates within 2–5 days (Thiemann et al. 2013, Rode et al. 2014). Grizzly bears (*U. arctos*) in Canada and black bears (*U. americanus*) in North Carolina, USA—trapped by foothold trap, helicopter darting, or barrel trap—showed an immediate effect of reduced movement rates, but returned to precapture movement rates within 1–1.5 months (Cattet et al. 2008). The greater influence on movement rates of wolves captured in foothold traps suggests that wolves may be more susceptible to foothold injury than are large carnivores (e.g., bears and cougars) possibly because of the wolves' smaller size.

Location of injuries from cable restraints appeared to facilitate faster recovery and quicker resumption of movements and activity patterns, even when comparing animals with similar no/low injury scores. The little information available on trapping effects on canid home ranges or areas of use suggests that carnivores are quite resilient to trapping. Wegan et al. (2014) reported no difference in the May to September home ranges of 2 GPS-radiocollared coyotes trapped between January and March in Michigan, USA. Although there is no reporting of the immediate area of use posttrapping, long-term home ranges of coyotes were not influenced by capture in cable restraints. Rather than abandonment of their home range, some animals may shift use within a home range in response to capture (Germano 2007).

There is a Russian proverb that states "The wolf is fed by its feet" (Bergman 2003). We show that cable restraint devices appeared to be an effective and humane method to capture wolves in winter with less injury (particularly to legs and feet) and subsequently a more rapid resumption of space use and activity patterns compared with foothold traps. We emphasize that differences in movement and space use was temporary, with wolves captured in foothold traps temporarily lagging behind snared wolves, but with both methods showing similar space use by 100 days postcapture. Even when gross examination showed no or low injury scores, cable restraints resulted in fewer leg or foot injuries than foothold traps. Although the single death during the study was a wolf captured in a cable restraint, it was the result of a "fixable" mechanical error. In our study, cable restraints were used exclusively in winter when foothold traps would result in frozen feet and toes or appendages. Oral injuries varied between the 2 techniques, with foothold traps causing more tooth damage and cable restraints causing more lip and gum damage. How these different mouth injuries affect wolf hunting and feeding is unknown.

MANAGEMENT IMPLICATIONS

Using cable restraints in winter has additional advantages including reduction in unintended captures (e.g., domestic dogs, bears, smaller carnivores), identification of travel routes in the snow for setting the devices, and easier access to remote areas from frozen rivers and lakes via snowmobile. On the downside, winter trapping may require more equipment for potentially processing the animal in subzero temperatures and more careful attention to set location choice to minimize risk of wolf entanglement or ungulate capture, and may pose logistical (e.g., securing restraints in frozen ground) and safety challenges for the capture team handling animals in cold temperatures. We encourage those considering deployment of cable restraints to consult with those experienced in their use; cable restraints appear to be a humane, selective, and efficient device that may expand capture opportunities and, depending on location and objectives, may offer methodological advantages over other methods, but their use requires proper training.

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