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Original Article

Efficacy of Travel Management Areas for Reducing Disturbance to Mule Deer During Hunting Seasons

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ABSTRACT For 50 years, the Oregon Department of Fish and Wildlife, USA, has designated travel management areas (TMAs) in which certain roads are closed to motorized traffic during hunting seasons with the goal of reducing disturbance to mule deer (*Odocoilius hemionus*). The efficacy of TMAs has not been tested. We measured the effects of temporary road closures on mule deer locations during the 2015 hunting season in 2 TMAs in eastern Oregon. We used data collected during 1 August–31 October 2015 from female mule deer ($n = 90$) fitted with Global Positioning System (GPS) transmitters programmed for a 13-hr fix interval. Euclidean distance to the nearest "closed" and "open" road was measured for each GPS location. Our results for Murderers Creek–Flagtail and Camp Creek TMAs were mixed but opposite to our predictions. Locations of deer that were nearer to open roads than closed roads were more frequent than expected for both TMAs. Mean distance from a deer location to a closed road was less than to an open road in both TMAs (85% less in Camp Creek and 21% less in Murderers Creek–Flagtail) but then in both cases, mean distance to any road (closed or open) was >2× greater inside the TMA than outside. Our results found no consistent effect of temporary demarcations of road closures in the TMAs. Management recommendations include designating a more even balance of closed and open roads for statistically improved monitoring of TMA efficacy, better enforcement of road closures during hunting seasons, and better demarcation (signage) of both closed and open roads in each TMA. © 2017 The Wildlife Society.

KEY WORDS eastern Oregon, GPS telemetry, hunter management, *Odocoilius hemionus*, wildlife disturbance.

The Oregon Department of Fish and Wildlife (ODFW), USA, has a long-standing concern that increasing road densities, and associated increased motorized traffic, on public lands in eastern Oregon may disturb mule deer (*Odocoilius hemionus*) movement patterns during autumn migration, which coincides with hunting seasons. Elsewhere, increased traffic has been found to cause increased disturbance to mule deer near roads, especially in open habitats (Behrend and Lubeck 1968, Rost and Bailey 1979, Swenson 1982, Johnson et al. 2004). The potential for this conflict in eastern Oregon motivated a management response as far back as 1967 when decreasing adult male deer ratios and increasing road densities on public lands led ODFW to designate its first cooperative travel management area (TMA). Within a TMA, all roads are temporarily "closed" to motorized traffic during hunting seasons to reduce disturbance to big game species, with exceptions being "open" roads posted with signs bearing round green reflectors. This "green dot system," by which only open roads are demarcated by signage, is opportunistically enforced by wildlife officers of the Oregon State Police, ODFW wildlife biologists, and U.S. Forest Service district rangers and employees. No physical barriers are used to close roads because of problems relating to enforcement and vandalism (ODFW 2003*a*,*b*).

With the TMA system having been in place for 50 years without any formal test of its efficacy, our objective was to take advantage of recent GPS telemetry data to test whether 2 TMAs in eastern Oregon are effective in reducing disturbance of mule deer, as indicated by the proximity of mule deer to roads during the closure period. We predicted that mule deer would be located further from open roads than closed roads inside a TMA and located further from roads in general outside a TMA compared with inside. We based these predictions on past studies that showed increased traffic caused increased disturbance to mule deer near roads (Behrend and Lubeck 1968, Rost and Bailey 1979, Swenson 1982, Johnson et al. 2004).

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STUDY AREAS

The Murderers Creek–Flagtail TMA was located within the Murderers Creek Wildlife Management Unit in the Aldrich

Mountains in Grant County, eastern Oregon. The elevation range was 731–2,131 m. Mule deer used this area for both summer and winter range. The climate was characterized by hot, dry summers (Jul mean max. = 33.4° C) and cold, wet winters (Jan mean max. = 7.4° C). Land cover across the higher elevation summer range (>850 m) was primarily coniferous forest dominated by ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*), whereas the lower elevation winter range had western juniper (*Juniperus occidentalis*) and mountain mahogany (*Cercocarpus ledifolius*) within a sagebrush (*Artemisia* spp.) matrix.

The Camp Creek TMA was located within the Northside Wildlife Management Unit in Grant County, eastern Oregon. Being higher in elevation (1,158–1,828 m) than Murderers Creek–Flagtail TMA, land cover across the entire area was a forest community dominated by ponderosa pine and Douglas fir, which mule deer occupied in summer and during spring and autumn migrations.

METHODS

Adult mule deer females were captured during March 2015 in a helicopter net-gunning operation in the Blue Mountains in eastern Oregon. All animals were humanely and ethically treated following capture procedures authorized by the Oregon Department of Fish and Wildlife and protocols prescribed by the American Veterinary Medical Association. Guidelines for the use of mammals in research (Sikes et al. 2011) were followed. Each deer was fitted with a Global Positioning System (GPS) collar (LifeCycle model; Lotek Wireless, Inc., Newmarket, ON, Canada) programmed for a location interval of 13 hr. The 13-hr interval resulted in a "rolling" time-stamp for sequential fixes so that locations of each collar were collected evenly through the 24-hr cycle. With each animal's collar operating on its own cycle, this ensured that the entire sample of locations was not influenced by time-specific animal activity. Collar fixes were uploaded to the GlobalStar platform once daily, from where we downloaded data to a desk-top computer with proprietary software (Lotek Wireless, Inc.). We reconstructed the downloaded location data from text files into a Geographical Information System (GIS) database (ArcMap Version 10.3; Environmental Systems Research Institute, Redlands, CA, USA) in which individual deer locations were plotted for the period 1 August–31 October 2015 and then we error-checked by identifying and removing duplicated and erroneous locations. This time window included prehunt scouting activity in the 3 weeks prior to the start of the archery season, the archery and rifle seasons lasting until mid-October, and then 2 weeks following the hunt during which we assumed deer would remain sensitized to human disturbance. Prehunt scouting activity involves motorized traffic to gain proximity to areas favored by mule deer, presumably resulting in some disturbance even though shots are not fired. For each TMA, locations were classified as either inside or outside the TMA with "outside" meaning within a 5-km-wide buffer zone around the perimeter of the TMA.

Within each TMA, we used the GIS to measure, for each deer location, the straight-line (Euclidean) distance to the nearest open and closed road, respectively. We then performed 3 sets of statistical analyses for each TMA. First, a paired Student's *t*-test was used to test our prediction that deer would generally be located nearer to closed than open roads. Second, total road distance in either "open" or "closed" designation was measured and then converted into the proportion that each represented in the total TMA road system. We then counted deer locations that were nearer to either a closed or open road and used a Chi-square goodness-of-fit test to compare the observed dispersion of deer relative to a random dispersion with expected frequencies calculated from the proportions of closed and open roads. If, for example, 70% of the road system was closed and if the deer were randomly dispersed, then we would expect the nearest road to be a closed road for 70% of locations. Third, we used a Student's *t*-test to compare mean distance from a deer location to the nearest road (closed or open) inside the TMA versus in the buffer zone outside. In all our analyses, we used proximity to roads as our response variable to align our tests specifically with the TMA management objective, which was to reduce disturbance by motorized traffic on roads. We avoided a habitat-based resource selection function approach because road placement was confounded with habitat type in this area.

RESULTS

Ninety collared mule deer females occupied our study areas during the study period, yielding 2,783 GPS locations (Table 1). The mean distance from a mule deer GPS location to the nearest closed road was significantly less than to the nearest open road in both TMAs (85% less in Camp Creek, $t_{80} = 11.3$, $P < 0.001$; 21% less in Murderers Creek–Flagtail, $t_{514} = 5.12$, $P < 0.001$). Across both TMAs, the dispersion of mule deer locations differed from random relative to locations nearer to open or closed roads ($\chi^2_1 = 2{,}652$, $P < 0.001$). The direction of the difference was, however, contrary to our prediction in that mule deer were more frequently located nearer to open roads than was expected (Table 1). Lastly, for both TMAs, the mean distance from a mule deer GPS location to any road (closed or open) was >2× greater inside the TMA than in the 5-km-wide buffer zone around it (Camp Creek, $t_{88} = 9.10$, $P < 0.001$; Murderers Creek–Flagtail, $t_{600} = 16.5$, $P < 0.001$).

DISCUSSION

Our results were mixed but, contrary to our prediction, we found no consistent effect of the "closed" road designation on the distance of mule deer from roads in TMAs during the autumn hunting season. Reasons could be attributed to mule deer behavior as well as some misconceptions in TMA management. When mule deer are exposed to motorized traffic along roads, they do not necessarily move far from the road but might simply move into cover (Johnson et al. 2004). The distance moved away from a road might be no >200 m, as was found in a study based on the locations of fecal pellet groups (Rost and Bailey 1979). Swenson (1982) studied the effects of hunting on habitat use by mule deer in Montana, USA, and found reduced use of coulee bottoms, plateaus, and

Table 1. Variables measured in Camp Creek and Murderers Creek–Flagtail traffic management areas (TMAs) in eastern Oregon, USA, based on Global Positioning System locations of marked mule deer during the autumn hunting season of 2015.

Variable	Camp Creek	Murderer's Creek
Area of TMA (km^2)	121	678
Total road distance (km) inside TMA	307	336
Closed road distance (%) inside TMA	83.7	96.2
Open road distance (%) inside TMA	16.3	3.8
Collared deer monitored in TMA	15	21
Total locations inside TMA	81	515
Collared deer monitored in 5-km buffer around TMA	23	31
Total locations in 5-km buffer around TMA	644	1,543
Observed locations nearer to closed roads	12	284
Expected locations nearer to closed roads	67.8	495.0
Observed locations nearer to open roads	69	231
Expected locations nearer to open roads	13.2	19.6
Mean ($\pm$SE) distance (km) to closed road in TMA	0.187 (0.015)	0.772 (0.032)
Mean ($\pm$SE) distance (km) to open road in TMA	1.250 (0.090)	0.973 (0.033)
Mean ($\pm$SE) distance (km) to any road in TMA	0.698 (0.046)	0.873 (0.027)
Mean ($\pm$SE) distance (km) to any road in 5-km buffer	0.265 (0.010)	0.419 (0.008)

ridgetops and increased use of upland timber cover and hillsides. Many U.S. Forest Service roads in eastern Oregon were built for timber harvesting and consequently routed for access to forested hills and hillsides, so habitat factors might over-ride the significance of the 'closed' designation of a road as far as mule deer are concerned. Finally, our study objectives were based on females and we acknowledge that there are sex differences in mule deer movement and habitat-use patterns (Dasmann and Taber 1956, Robinette 1966, Brown 1992).

Our results appear contradictory in that deer inside both TMAs were located, on average, closer to "closed" than "open" roads, but then the frequencies of sightings that were closer to "closed" roads were significantly less than expected from the proportions of "closed" road distance. However, in both TMAs the roads are mostly designated as "closed" (84% and 96%) and so it could be expected that the closest road to a deer would be "closed." Consequently, the result of the goodness-of-fit test, which controlled for that problem, was more insightful. This conclusion was further supported by the finding that the mean distance from a deer to any road was actually greater (more than double) inside both TMAs than in the 5-km-wide buffer zones outside.

The most likely reason for our results being contrary to our prediction (and the ODFW management objective) is the weakness of the assumption that designating a road as "closed" actually results in it being closed. Hunters who respect the designation for motorized traffic may still use "closed" roads with pack animals and were likely to choose such roads for that purpose. Also, with no physical barriers to block motorized access to "closed" roads, a road's designation only posted with "green dot" signage for "open" roads, and only opportunistic enforcement by agency personnel, the risk of penalty is a weak deterrent against intentionally or unintentionally breaching TMA regulations. Finally, our finding that mule deer were located, on average, further from any road in the TMA than any road in a 5-km-wide buffer zone outside the TMA could be simply self-explanatory. These TMAs were popular areas for hunters, which is why they were proclaimed as TMAs in the first place, and so they received comparatively heavy traffic in the hunting season.

MANAGEMENT IMPLICATIONS

The TMA road-closure policy as it is currently implemented does not appear to be achieving its objective. If the policy is to be maintained, then we recommend that it be implemented with several changes that would have minimal cost implications. Contemporary thinking on the stewardship of social–ecological systems emphasizes the principle of adaptive management, which is particularly applicable to wildlife management (Allen et al. 2011). Central to that principle is the requirement for effective monitoring to feed back into objective-setting and management implementation. To achieve better monitoring of TMA efficacy with improved statistical tractability, we recommend that designations of open and closed roads be more evenly balanced with regard to proportional distances in each category and the habitat types in which they are located. Maps available at all entrances to TMAs should clearly indicate which roads are closed and open, and the "green dot" signage for open roads should be extended to "red-dot" signage for closed roads. Such signage should be posted at all road entrances and intersections. Thereafter, if our study were to be replicated and no effect still found, then the TMA policy should either be discontinued or implemented with physical road closures and enforcement, followed by further monitoring.

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