Biological Conservation 181 (2015) 44–53

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Underreporting of wildlife-vehicle collisions does not hinder predictive models for large ungulates

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ARTICLE INFO

Article history:
Received 16 June 2014
Received in revised form 21 October 2014
Accepted 27 October 2014

Keywords:
Accident
Animal–vehicle collision
AVC
Carcass data
Moose
Reporting bias
Road
Road-kill
Survey error
White-tailed deer
WVC

ABSTRACT

Conflicts from wildlife–vehicle collisions (WVCs) pose serious challenges for managing and conserving large ungulates throughout the world. However, underreporting of large proportions of WVCs (i.e., two-thirds of WVCs in some cases) creates concern for relying on governmental databases to inform management strategies of WVCs. Our objective was to test the sensitivity of WVC studies to underreporting using 2 species of large ungulates that experience substantial incidences of collisions but exist in different environmental settings: white-tailed deer (*Odocoileus virginianus*) in agricultural-dominated central Illinois and moose (*Alces alces*) in forest-dominated western Maine, USA. We estimated baseline relationships between the landscape, traffic, and abundance of wildlife on the probabilities of WVCs using the total number of reported WVCs. Then, we simulated underreporting by randomly excluding reports of WVCs and evaluated for relative changes in precision, parameter estimates, and prediction. Point estimates of the relationships between environmental influences and WVCs for both species were reliable until high rates of underreporting occurred (⩾70%). When underreporting occurred with spatial bias, shifts in point estimates were detected only for variables that spatially-corresponded with the rate of reporting. Prediction estimates for both species were also reliable until high rates of underreporting occurred (⩾75%). These findings suggest that predictive models generate reliable estimates about WVCs with large ungulates unless underreporting is severe; possibly because they occur in non-random patterns (i.e., hotspots) and variability in their environment influences is low. We recommend that concern about underreporting not impede research with existing databases, such as those in this study, for analyzing predictive models and developing management strategies for reducing WVCs.

1. Introduction

Vehicular collisions with wildlife are one of the most widespread and persistent human–wildlife conflicts that exist throughout the United States and the world (Conover, 2010; Huijser et al., 2009). Predictive studies are used to identify high risk locations of WVCs for many species (Gunson et al., 2011), but these studies are afflicted by various sources of measurement error. These errors include: (1) the incidences of WVCs are underreported (e.g., Donaldson and Lafon, 2010), thus many WVCs are excluded from study or misclassified as non-collision locations, (2) the spatial locations of WVCs are inaccurately reported (e.g., Gunson et al., 2009), and (3) the attributes of the environment near WVCs (e.g., land cover) are misclassified (e.g., Foody, 2002). In this manuscript we focus on the primary source of error, underreporting. To our knowledge, no studies have examined the extent at which underreporting effects predictive models of WVCs.

The degree of underreporting for WVCs is particularly concerning for natural resource and transportation managers that attempt to reduce collisions with large ungulates. These collisions represent the most dangerous WVCs for humans (Huijser et al., 2008), and fatalities have increased 104% since 1990 (Sullivan, 2011). Reducing collisions relies on accurate information about the ecological drivers of WVCs to determine cost-effective mitigation strategies (Forman et al., 2003). However, obtaining reliable information is difficult because two-thirds or more of WVCs go unreported in national crash databases each year in the United States (Huijser et al., 2008). This large amount of underreporting may reduce the ability to distinguish ecological drivers of WVCs, or shift the estimates of statistical relationships if underreporting is unevenly distributed throughout an area of study (i.e., spatially biased; Groves, 2004; Lavrakas, 2008).

Reporting of WVCs generally consists of 2 data collection methods: (1) collision reported data, or (2) carcass removal data (Donaldson and Lafon, 2010; Huijser et al., 2007; Lao et al.,

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http://dx.doi.org/10.1016/j.biocon.2014.10.030
0006-3207/

2011). Collision reported data are afflicted with underreporting because some WVCs include insufficient property damage to warrant reporting; motorist decide not to report; or police, natural resource, and transportation agency conclude that the accident does not merit reporting (Huijser et al., 2008). Carcass removal data are afflicted with underreporting because of long time intervals between carcass collection activities, injured animals move away from roads following collisions (e.g., Snow et al., 2012), carcasses are scavenged or decomposed, carcasses are out of sight and not detected, or the carcass is not a species of concern (e.g., Knapp et al., 2005; Olson et al., 2014). Reports of WVCs are usually greater in number for carcass removal data (e.g., Donaldson and Lafon, 2010), but the spatial coverage of carcass removal datasets often vary based on program funding and prioritized roads for carcass removal (e.g., Knapp et al., 2005). Also, not every state or county collects carcass removal data. Therefore, we chose to examine records of WVCs from governmental databases of collision reported data.

We examined collisions reports for 2 species of large ungulates that experience frequent WVCs and cause concern for human safety and property damage. Collisions with white-tailed deer (*Odocoileus virginianus*; Zimmermann, 1780) are the most frequently reported WVCs, estimated at >1 million each year in the United States (Conover et al., 1995). Deer–vehicle collisions generate the highest amount of monetary damage from WVCs, averaging $6717 per collision (Huijser et al., 2008). Collisions with moose (*Alces alces*; Linnaeus, 1758) generate the highest rate of human injuries and death. Up to 10% of collisions with moose result in human injury or fatality (Huijser et al., 2008). Databases of these WVCs provided the opportunity to independently assess sensitivity of predictive models to underreporting for 2 large ungulates that exist in differing environments with differing traffic regimes and population abundances.

The departments of transportation in Illinois and Maine prioritize collecting reports of deer– and moose–vehicle collisions, respectively. In Illinois, the reports are used to inform deer management strategies (University of Illinois Extension, 2013) and the reports in Maine provide information for managing moose–vehicle collisions (Maine Interagency Work Group of Wildlife/Motor Vehicle Collisions, 2001). Not all WVCs were accounted for because of underreporting, therefore we used 100% of the reported deer– and moose–vehicle collisions in these databases as baselines to approximate the true relationships between environmental variables and the probabilities of collisions. Thus, the baselines were limited in scope to the number of reported collisions.

The central question prompted by underreporting is whether statistical modeling of environmental conditions associated with WVCs is affected by lack of precision (i.e., estimates of regression coefficients with high degrees of uncertainty) or bias (i.e., inaccurate estimate of regression coefficients). Generally, statistical models are used to compare sites of collisions and non-collisions using logistic regression models and information theoretic procedures to evaluate how the landscape, traffic, and abundance of wildlife influence the probability of WVCs (Gunson et al., 2011). Regression coefficients and 95% confidence limits (CLs) are used to determine which variables influence the probability of WVCs (e.g., Danks and Porter, 2010; Finder et al., 1999; Snow et al., 2011) and infer management implications for reducing WVCs.

Our objective was to evaluate the sensitivity of statistical models that use collision data for detecting influences on the probability of WVCs from the surrounding landscape, traffic, and abundance of wildlife under varying degrees of underreporting. We used all of the reported collisions with deer and moose, respectively, to estimate baseline relationships between the environmental variables and the probabilities of deer– and moose–vehicle collisions. Then, we simulated underreporting of collision data by removing records of WVCs, and examining the potential impacts for (1) reduction in precision of regression coefficients, (2) shifts in the regressions coefficients, and (3) reduction in the predictive power of models as underreporting increased. We sought to identify thresholds in reporting rates where precision, shifts in coefficients, and prediction became unstable and generated unreliable inferences. Our intent was to evaluate whether effects of underreporting were generalizable across different environmental conditions associated with different ecoregions, traffic, and population abundances by comparing WVCs with deer in Illinois and moose in Maine.

2. Materials and methods

2.1. Study area

Our study area (Fig. 1) included 50 counties in central Illinois (77,655 km^2) and portions of 3 counties in the western Maine (10,721 km^2). The vegetation in central Illinois was characteristic of the temperate, Prairie Parkland ecosystem province (Bailey, 1980, 1995). The landscape contained agriculture (74%), development (9%), intermixed deciduous trees (1.5%), and prairies and groves (<1%). Row crops are comprised primarily of a corn and soybean matrix (Rosenblatt et al., 1999). Central Illinois contains 71,498 km of public roads, for an overall road density of 0.9 km/km^2. During 2007–2008, density estimates for deer within central Illinois were estimated at 6.1–25.2 deer/km^2 (Anderson et al., 2013).

Vegetation in western Maine was characteristic of the Adirondack–New England Mixed Forest–Coniferous Forest–Alpine Meadow ecosystem province (Bailey, 1980, 1995; Maine Office of GIS, 2010). Vegetation in western Maine was composed of deciduous, conifer, or mixed forests (85%), interspersed shrub wetlands (6%), and development (3.5%). Western Maine contains 2474 km of public roads, for an overall road density of 0.2 km/km^2. The densities of moose in and near this region were estimated to be approximately 0.4–4.0 moose/km^2 during 2010–2011 (Kantar and Cumberland, 2013).

2.2. Study design

For each species, we attempted to reduce nuisance uncertainty in our predictive models from environmental variation by selecting study areas with evenly distributed human populations (i.e., no large cities) and uniform landscapes. For each species, we also attempted to reduce nuisance uncertainty from small sample sizes. Substantially more deer–vehicle collisions were reported annually in Illinois than moose–vehicle collisions in Maine, therefore we examined 1 year of collisions in Illinois and combined 10 years of collisions in Maine. Reports of moose–vehicle collisions in western Maine did not fluctuated widely (i.e., 100–160 collisions/yr.) during the last 2 decades (Danks and Porter, 2010), therefore combining years was reasonable.

Underreporting confounds identification of non-collision sites because (1) either no WVC occurred, or (2) a WVC occurred but was not reported. We included this uncertainty into the study by generating a set of independent, systematic sites for each species that were $\geqslant$1.5 times the number of reported collisions for each species. We generated 1.5 times more systematic sites to create a large enough pool to draw new samples of independent sites for the simulations described below. The systematic sites were generated along the study roads at intervals of 5000 m (n = 14,306 random points) for deer, and 500 m for moose (n = 4877 random points) to create the desired sample size using ArcGIS (v10.1; Environmental Systems Research Institute, Inc., Redlands, CA).