Using Volunteer Wildlife Observations to Plan Mitigation on Highways

FRASER M. SHILLING, Department of Environmental Science and Policy, University of California, One Shields Avenue, Davis CA 95616
530-752-7859 (ph); 530-752-3360 (fax); fmshilling@ucdavis.edu

DAVID P. WAETJEN, Department of Environmental Science and Policy, University of California, One Shields Avenue, Davis CA 95616
530-752-2913 (ph); 530-752-3360 (fax); dwaetjen@ucdavis.edu

BARBARA CHARRY, Maine Audubon, 20 Gilsland Farm Road, Falmouth, ME 04104
207-781-2330 ext. 225 desk phone, 207-781-0974 (FAX); bcharry@maineaudubon.org
ABSTRACT

Understanding wildlife occurrences and movements in relation to highways is essential to state Departments of Transportation contributing to stewardship of ecosystems. For terrestrial vertebrates in most places, roads and related human infrastructure degrade habitat quality, fragment populations and become major barriers to movement. Collecting observations of wildlife-vehicle collisions (WVC) is often either carried out by specialists, but narrow in time and space, or is carried out widely by highway maintenance staff, but is narrow in taxonomic breadth. To understand the significance of WVC locations for both conservation and driver-safety concerns, it has become necessary to develop WVC observation systems that are both extensive (i.e., state-scale) and intensive (i.e., detailed and accurate observation data). Since September, 2009, >26,000 independent observations of >400 vertebrate species have been recorded in online, state-scale (CA and ME), form-based informatics system by >1,200 observers. We asked the question whether or not WVC observations collected by these two existing large-scale volunteer-science networks could be used to inform transportation-mitigation planning. Cluster analysis of volunteer-observed WVC was performed using spatial autocorrelation tests for 16 state highways and interstates. These clusters were compared to similar findings from DOT-collected WVC data. We show that volunteer-collection of WVC at state-scales could be useful in prioritizing mitigation action by state DOTs to protect biodiversity and driver safety.

KEY WORDS Transportation, Wildlife-Vehicle Collisions, Roadkill, Informatics, Citizen Science, Wildlife Observation, Wildlife Movement
INTRODUCTION

Wildlife-vehicle collisions (WVC) are a large and growing concern among Departments of Transportation (DOT), conservation organizations and agencies, and the driving public (Huijser et al., 2008). WVC with most animal species is a conservation concern (Fahrig and Rytwinski, 2009) and when the animal is large (>100 kg), a safety concern as well (Bissonnette et al., 2008). Many DOTs are trying different methods of reducing WVC, including fencing roadways and providing crossing structures across the right-of-way to allow safe animal passage. WVC occur when traffic coincides with a place where animals decide to cross the surface of a roadway.

Predicting and prioritizing these places for mitigation of impacts to wildlife and drivers is an important step in reducing the conflict. To inform these types of predictions and corresponding mitigation at a large scale (e.g., a US state), it becomes necessary to collect accurate WVC data. One common finding with spatial analysis of WVC is that collisions are clustered, which often leads to analysis of proximate causes of clustering for individual species (e.g., road or landscape features; Gunson et al, 2011). One approach is to use previous collisions to develop predictive landscape models to find “hotspots” (Nielsen et al., 2003; Langen et al., 2009; Gunson et al., 2011), or seasonality models to find “hot moments” (Beaudry et al., 2010). This is often done for ungulates because collision with ungulates is both a conservation and safety concern (e.g., Danks and Porter, 2010). There are various costs associated with a collision between a deer and a vehicle; on average, a collision with a deer costs $6,671 (Hujser et al., 2009). This kind of cost-equivalent means that WVC can be measured in terms of their cost to society, which can matter regardless of clustering of WVC. Less well-studied than WVC clustering is the idea that for broad taxonomic groups, “sheet flow” of animals may result in WVC everywhere and statistically-significant clustering may only be found because of limitations in the study area, or data collection. Although understanding clustering for individual species is important for each of those species in each of its habitats and landscapes; for highway planning, it is also important to understand whether or not and why there are patterns of WVC for most or all vertebrate fauna present in an area.

Monitoring biodiversity and investigating causes of changes in biodiversity allows society to make decisions about conservation (Wilson, 1999; Devictor et al., 2010; Bang and Faeth, 2011; Corona et al., 2011) and improve management of human-wildlife conflict. Involving volunteers from the public in monitoring biodiversity is a powerful idea. Projects involving volunteer scientists have grown considerably in recent years (Silvertown, 2009, Conrad and Hilchey, 2010). There are a number of benefits to including volunteer scientists as participants in wildlife monitoring programs. First, the data collection efforts can be spread over a larger area, such as a US state or country (Devictor et al., 2010). Secondly, the increase in observation data can be significant as more participants in the project are added and data collected by volunteers is used in ecological studies, such as those of wildlife-vehicle mortality on roadways (Kinley and Newhouse, 2009; Lee et al., 2006). Thirdly, when private citizens are involved in collecting data about wildlife, they become re-connected to nature (Devictor et al., 2010) and the difficult problem of conserving wildlife in mixed ownership and use landscapes is more easily accomplished (Cooper et al., 2007), especially if the mitigation costs are likely to be high.
The goal of this study was to test whether observations collected by volunteers using an online reporting system in two US states (CA and ME) could be used to inform transportation planning. The objectives were 1) to understand if WVC observations collected by volunteer scientists could be used to inform WVC hotspot analysis and 2) to locate WVC hotspots on highways in two US states. We describe the use of data from state-scale, online observational networks for roadkill-wildlife occurrences in California (CA) and Maine (ME). The system followed a reproducible approach that allowed verification of observation accuracy and easy access to the data collected for analysis using other available tools. We used spatial-autocorrelation tests (Morans I and Getis Ord, Gi*) to determine the significance of a “spot” or a roadway segment in relation to the neighboring segments. We found that there were sufficient data to identify statistically-significant “hotspots” for many of the states’ highways. We propose that novel online, volunteer-based systems like these could be used to augment the efforts of state DOTs and wildlife agencies and help inform location and type of mitigation actions.

STUDY AREA

The two states were chosen for the availability of existing large-scale, online systems of volunteer-collected WVC data. At the time of writing, both systems were being actively used. The California Roadkill Observation System (CROS, http://www.wildlifecrossing.net/california) was launched in August 2009 to allow volunteer scientists to record carcass observations on California roads and highways. California has a population of more than 37 million people and >499,000 km of roadways networked across 411,000 km² of varied land cover types, including urban, agriculture, forests, grasslands, and desert. Of these roadways, 196,381 km are major roads, and 25,041 km are highways. Six example highways were chosen in CA for geospatial analysis: interstate 5, interstate 280, state route (SR) 50, SR 70, SR 94, and SR 190 (Figure 1). A similar system was developed in early 2010 for Maine, the Maine Audubon Wildlife Road Watch (http://www.wildlifecrossing.net/main), to allow collection of both live and dead animal observations on and adjacent to Maine’s roads and highways. Maine has a population of 1,328,000 people and >60,600 km of roads, including 10,900 km of highways, across its 84,000 km² of forests, wetlands, agricultural areas and townships. Ten example highways were chosen in ME for geospatial analysis: interstate 295, a combination of SR 2, 7 & 9, SR111, SR 116, SR 122 127, and a combination of SR 39, 202, & 100A (Figure 1).
Figure 1. Study area and highways. State highways in each state are shown in light gray and each study highway in black.

METHODS

Volunteer Observers

Volunteer observers were members of the California Roadkill Observation System (CROS) or the Maine Audubon Wildlife Road Watch (MAWRW). CROS members were recruited initially through the list-serve of the UC Davis Road Ecology Center in Fall, 2009. More members subsequently joined at various times, upon hearing or reading about the system through email list-serve, media, or word-of-mouth pathways. The recruitment process was very passive and contact with prospective or actual members of the system brief and infrequent. Members of CROS can participate through defined survey routes that they identify and monitor, or through providing opportunistic observations. MAWRW volunteers participate through reporting opportunistic observations, regular surveys of a self-selected targeted survey route (Adopt-A-
Volunteers participating in reporting opportunistic observations in either state were not given any training other than instructions on the website. Training for Maine’s Adopt-A-Road was provided in written protocols exclusively online. Maine ESRW volunteers were trained on field-data-collection protocols, species identification, and the purpose of the project at a half day workshop. Telephone and email support was offered to volunteers for all efforts. Maine Adopt-A-Road volunteers could choose 1 mile walking or 10 mile driving survey routes. Maine ESRW volunteers were assigned 1 mile walking survey. California survey route volunteers chose a driving route of a certain length, then carried out surveys at a frequency they set.

161 Volunteer WVC Record Collection

The observation record included several fields, which were present for any type of observation, including the ubiquitous attributes for collecting the “who”, “what”, “where”, “when”, and “how” of an observation. There are also fields that are specifically related to the wildlife observations and transportation. Data entry for location was usually made through an interactive map interface on the website, or by directly entering the latitude and longitude. A single observation permitted only one animal species name to be associated with each record. The system also provided a facility where observations could be managed based on the species observed and the IUCN conservation status of that species in the region. For example, observations of two endangered turtle species (ME: Blanding’s turtle, *Emydoidea blandingii*, and box turtles, *Terrapene* spp.) and two vulnerable species (ME: spotted turtle, *Clemmys guttata*, and Wood turtle, *Glyptemys insculpta*) were automatically cached from public view to protect turtle populations from illegal collecting.

Data were downloaded for each of ME and CA from their respective online systems. Data ranges for ME were June, 2010 to May, 2013 and for CA August, 2009 to July, 2013. WVC for specific highways were selected by hand based on their proximity to the highway. Any question about which of adjacent roadways a WVC was co-located with was resolved by referring to the WVC record, which includes a narrative description of the site of observation.
Agency WVC Record Collection

Caltrans maintains databases for carcass retrieval by District maintenance staff and for deer-vehicle-collisions (DVC) requiring a report and attendance by the California Highway Patrol. Partially-complete data-sets were retrieved from Caltrans using a request under the California Public Records Act. Data for portions of two Districts (3 & 4), were the most complete for carcass retrieval and accident reporting. Carcass retrieval data for 1984-1997 and 2001-2009 and DVC data for 2008-2010 were obtained for District 3, SR50, and carcass/DVC data for 2005 – 2012 were obtained for District 4, I-280. DVC were summarized by post-mile for each highway, both of which also had a large number of volunteer observations.

191 Transportation Management Nexus: WVC Hotspot Analysis

Two types of “hotspot” analysis were conducted: a test for spatial autocorrelation, which identifies highway segments statistically-different from their neighbors, and calculation of WVC density (# WVC/mile-year), which allows comparison of WVC against some threshold of concern (Wang et al., 2010).

Study highways in each of California and Maine were tested for sufficient density of observations across 1-mile highway segments (>10 WVC/mile for at least one segment) and length of time of surveying (>1 month). Each highway was dissolved into one long segment and subsequently cut into regular-length segments of 0.25, 0.50, or 1.00 mile. These lengths were chosen because of previous research indicating that these are appropriate road segment lengths for studying wildlife crossings and WVC (Malo et al., 2004; Taylor and Goldingay, 2004). WVC observations were forced into co-location with their respective interstates using a “snap to line” tool (https://github.com/robintw/RTWToolsForArcGIS) implemented in ArcGIS. The “spatial join” tool was used to sum the number of observations per line segment and these sums per line segment length were used as the basis for density-based analyses and for subsequent spatial autocorrelation analysis. We also used estimates of the total cost of deer-vehicle collisions to provide estimates of the cost per mile segment per year from deer-vehicle collisions (Hujser et al., 2009). This provides another way to prioritize areas for mitigation, including both spatial location and economic benefits from mitigation action.

Moran’s I and the Getis-Ord Gi* z-score statistic (Getis and Ord, 1992) were used to determine whether or not WVC observations in California and Maine were spatially clustered in “hotspots” along highways. The Moran’s I tool in ArcGIS 10.1 was used to test for spatial autocorrelation among interstate line segments and to determine the threshold distance to use in calculating the Getis-Ord Gi* z-score. The threshold distance was determined to be the segment length at which the Moran’s I value was 90% of the peak value. The Getis-Ord Gi* z-score is a measure of the statistical significance of clustering for each analysis unit, in this case highway segments. The Getis-Ord Gi* z-score was calculated for different lengths of highway segment, which can affect where hotspots are identified. Shorter segment lengths (e.g., 1/10th of a mile) may result in more hotspots than longer segments (e.g., 1 mile) because there is greater likelihood at shorter distances that there will be a difference between # carcasses averaged over segments than at greater distances.
RESULTS

Volunteer-Observations

Walking surveys as required by the ESRW reported significantly higher number of amphibians and reptiles than the random observations with amphibians 33% ESRW and 4% random, reptiles 13% ESRW and 7% random, birds 26% ESRW and 17% random, and mammals 28% ESRW and 71% random through June 13, 2013. In general, in both states, many more species are observed when the survey mode is walking, and necessary to record data for amphibians and reptiles. In 2012, 7 of 22 ESRW routes surveyed reported no or only one wildlife observations for all surveys conducted. This absence of observations is important data that can only be collected through regular targeted surveys. Through this we may be able to learn whether the road and surrounding habitat is acting as a severe barrier to wildlife movement, which times of day and types of weather that are most effective for making observations, and the frequency of surveys needed. Volunteers were required to survey 8 times in 6 months. One route surveyed in 2012 and 2013 was surveyed only 7 times in 2012 each time with no wildlife observations. So far in 2013 the route has been surveyed 17 times by the same volunteer who has reported 3 wildlife observations. The number of volunteers was increased on each route in 2013 to increase survey effort without over taxing the volunteer base. Volunteers were also asked to increase their survey frequency but were still only required to commit to 8 surveys. In CA, all observations collected were opportunistic, with no regular surveying of particular routes.

WVC Hotspots

Transportation and wildlife agencies often want to know the locations of hotspots of wildlife-vehicle collisions in order to design appropriate mitigation actions. We tested the utility of the WVC observations collected by volunteers along frequently-surveyed highways in CA (Figure 2) and ME (Figure 3) in identifying collision hotspots. For characteristic sections of highway statistically-significant clusters of WVC observations and locations of high-densities of WVC were identified (Table 1).
Figure 2. Distribution of statistically-significant clusters of WVC (dark gray) along study highways in California. WVC are indicated with white circles. A) Interstate-5, B) SR 70, C) SR 94, D) SR 190
Figure 3. Distribution of statistically-significant clusters of WVC (dark gray) along study highways in Maine. WVC are indicated with white circles. A) Interstate 295; B) State routes 2, 7, 259 and 9; C) State route 111; D) State routes 127; and E) State routes 39, 202, and 100A.
Table 1. Highway and volunteer WVC-observation summary. In every case in CA, except interstate 5, the study highway length was a subset of the entire shield highway length. “Time” refers to the number of months between the first and last observation. “# Hotspots” was determined by counting unique, non-overlapping locations of autocorrelation, or number of miles where >1 WVC/yr was observed.

<table>
<thead>
<tr>
<th>Study Highways (Length, mi)</th>
<th># Observers</th>
<th># Observations (# Species)</th>
<th>Time (# months)</th>
<th># Hotspots (spatial autocorrelation)</th>
<th># Hotspots (WVC density &gt;1/mi-yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME I-295 (56)</td>
<td>23</td>
<td>320 (26)</td>
<td>27</td>
<td>7</td>
<td>46</td>
</tr>
<tr>
<td>ME SR 2,7,9 (24)</td>
<td>5</td>
<td>67 (12)</td>
<td>29</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>ME SR 111 (14)</td>
<td>2</td>
<td>31 (11)</td>
<td>20</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>ME SR 116 (22)</td>
<td>1</td>
<td>45 (12)</td>
<td>2.5</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>ME SR 127 (15)</td>
<td>3</td>
<td>46 (17)</td>
<td>14</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>ME SR 39,202,100A (25)</td>
<td>5</td>
<td>171 (25)</td>
<td>29</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>CA I-5 (797)</td>
<td>62</td>
<td>1,131 (62)</td>
<td>47</td>
<td>42</td>
<td>54</td>
</tr>
<tr>
<td>CA SR 94 (21)</td>
<td>6</td>
<td>776 (60)</td>
<td>38</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>CA SR 190 (50)</td>
<td>11</td>
<td>531 (46)</td>
<td>43</td>
<td>14</td>
<td>34</td>
</tr>
<tr>
<td>CA SR 70 (129)</td>
<td>36</td>
<td>392 (30)</td>
<td>38</td>
<td>19</td>
<td>73</td>
</tr>
<tr>
<td>CA SR 50</td>
<td>18</td>
<td>372 (26)</td>
<td>40</td>
<td>10</td>
<td>29</td>
</tr>
</tbody>
</table>

Hotspots and Mitigation Planning

Identifying locations of clustering of WVC is one type of information useful for transportation mitigation planning. Identifying locations of high-cost from deer-vehicle collision (DVC) is another type. We compared the occurrence of statistically-significant WVC clusters, based on volunteer observations (Figure 4A), with similar clusters of DVC observations, based on DOT observations (Figure 4B). Although there was no overlap of clusters between these data sources identified by analysis of spatial autocorrelation, there was one location (boxed in Figures 4A and 4C) that was both a hotspot identified by volunteer observations and a location of high estimated cost of DVC from DOT observations. For SR 50, the estimated annual cost of DVC ranged from <$500 to almost $12,000 per mile (Figure 4C). For I-280, the estimated cost of DVC was higher.
than for SR 50, reflecting a higher rate of DVC, and varied from <\$1,000 to >\$40,000 per mile (Figure 4D).
Locations of potential areas for mitigation. A) Statistically-significant clusters using volunteer observations; B) statistically-significant clusters using DOT observations; C) SR 50 rates of DVC per post-mile (points) and associated costs ($/mile); and D) I-280 rates of DVC per post-mile (points) and associated costs ($/mile).

DISCUSSION

We demonstrate that volunteer observations of WVC from across a broad taxonomic range can be used in WVC hotspot identification on state highways. Within each of CA and ME, the systems described here represent the most extensive and taxonomically-broad wildlife monitoring effort, providing information about herpetofauna, birds, and mammals. The opportunistic wildlife observations in our systems may provide the raw data for statistical analyses of proximate contributors to wildlife-vehicle collisions and planning for minimizing WVC impacts on wildlife and drivers. Targeted surveys could be used to understand the impact of WVC on local wildlife populations, a critical need in understanding and mitigating transportation impacts (Fahrig and Rytwinski, 2009).

We demonstrate here that a network of volunteer observers can be established at the state scale and provide information potentially-useful to DOTs in planning mitigation. In ME, records of all wildlife observations from 2012 were shared with Maine Audubon’s project partner the Maine Department of Transportation (MDOT) for use in their project scoping process. Maine Audubon plans to continue annually to provide them with all observations as well as results from hotspot and density analysis. The plan is to identify where areas of conservation concern overlap with MDOT projects in their 3-year plans. Where there is overlap through assessment of the habitats, species types, and road characteristics, projects can be designed to mitigate impacts to wildlife and public safety and enhance wildlife movement. In addition, locations of hotspots and high density of live and dead wildlife observations will be shared with local citizen science volunteers for them to share and work with their towns planning and road departments for local road project mitigation.

Wildlife-Vehicle Collisions

Animals die as result of collisions with traffic because of traffic speed, traffic volumes, seasonal changes in movement, separation of important habitat areas, occluded line-of-sight, and other factors (Hobday and Minstrell, 2008; Litvaitis and Tash, 2008). Most of the observations of dead animals made using the online, state systems described here were opportunistic and thus do not reflect actual rates of WVC on a particular roadway. WVC may occur and not be observed, be removed by highway maintenance crews, or be scavenged by other animals. Scavenging rates can be very high for roadkilled animals, affecting confidence in estimates of total impact of wildlife-vehicle collisions on populations (Antworth et al., 2005; Barthelmess and Brooks, 2010). The observations do reflect the presence of particular species at particular times of year and thus are a presence-only type of record useful in understanding wildlife distribution and movement, and for roadkilled animals, proximate causes of the collision or, as demonstrated here...
for frequently-driven roads, spatial-aggregation of collisions. Large-extent databases of WVC observations provide a tool for developing and testing predictive models for contributing factors to wildlife-vehicle collision. Because of unevenness in sampling and the unknown level of effort going into opportunistic reporting in the systems described here, we are not in a position to rank risks to wildlife among highways. However on single routes, one may be able to locate local hotspots (blind curves, riparian crossings) and calibrate observations per unit effort, relative visibility and reporting rates for different species, and related correction rates.

Mitigation Planning

We demonstrate that volunteer-observations of WVC can contribute to understanding locations of WVC clusters that could be suitable for mitigation action. These hotspots may not align with clusters identified using DOT-collected WVC observations, because the latter are typically of ungulate species. The combination of high-species-diversity observations by volunteers and DOT/wildlife agency observations could provide the ideal combination of WVC data to directly inform mitigation planning that provides both conservation and driver-safety benefits.

The annual cost of deer collisions, varied between the two CA state-highways analyzed and ranged from <$500 to >$40,000 per mile. To put this number in perspective, it can cost ~$20,000/mile to augment a 5-6 foot chain link fence to make it an 8-foot fence (e.g., deer-fence in ID, [https://fishandgame.idaho.gov/content/post/i-15-mule-deer-fence-near-pocatello-complete](https://fishandgame.idaho.gov/content/post/i-15-mule-deer-fence-near-pocatello-complete)) and up to $100,000/mile to construct a new 8-foot fence. Fences are typically associated with purpose-built, or other structures that allow wildlife passage across a right-of-way. There were segments of high costs from deer collisions (>$5,000) throughout both SR 50 and I-280. Fence/crossing mitigation of certain stretches of state highway could pay for themselves in terms of avoided costs from deer collisions in a matter of 1-20 years, depending on rate of collision and existing fence infrastructure.

Many segments of the state highways studied are likely to have collisions between vehicles and any animal, including deer. These areas may be predictable, but what is certainly predictable is that providing directional fencing to encourage deer and other wildlife to usable crossing structures will reduce collisions with vehicles. Directional fencing and accompanying structures (e.g., jump-outs to allow animal escape from the road-side of a fence) have proven to be effective for reducing collisions between deer and vehicles. Directional fencing, electrified mats (Seamans and Helon, 2008), and under-crossings (Hedlund et al., 2004) can be very useful at reducing wildlife-vehicle-collisions. This utility is predictably compromised if the structures and materials are not monitored and maintained. What this means is that animals will enter the roadway if structures are not maintained. At the scale of whole states and state highways, these structures will seem expensive, thus placing them strategically, and showing their potential and actual cost-effectiveness will be very important.
ACKNOWLEDGMENT

The authors would like to thank Maine Audubon and Together Green, Maine Outdoor Heritage Fund, and Transwild Alliance for partial funding for development of the Maine web-site. The I-280 project cited was supported by agreement 04A3757 between the University of California, Davis and Caltrans. The remaining effort was contributed by the authors. The authors give a special thanks to Dr. Doug Long of the Oakland Museum of California for his many WVC observations and his help with species-identity verification. The authors would also like to thank the >1,200 volunteer observers who have contributed observations to the project. The authors have no conflict of interest related to this study.

LITERATURE CITED


