NDOT Research Report

Report No. 342-18-803 TO 2

DEVELOPMENT OF NEVADA HIGHWAY FENCING GIS DATABASE

August 2019

Nevada Department of Transportation

1263 South Stewart Street

Carson City, NV 89712

Disclaimer

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16. Abstract

The Nevada Department of Transportation (NDOT) has been installing wildlife fences along interstate/state highways where wildlife-vehicle collisions (WVCs) concern exists. A fencing geographic information system (GIS) dataset can be used to coordinate the locations and construction of new wildlife crossing structures and wildlife fences. A statewide fencing GIS database is also essential for rural highway safety analysis, especially when it is integrated with crash data, wildlife animal migration data, road properties, and existing crossing structure data. The Center for Advanced Transportation Education and Research (CATER) at the University of Nevada, Reno (UNR) developed a Nevada statewide highway fencing database in this project by reviewing multiple data sources such as Google Earth Pro, Google Maps, Google Street View, Bing Maps and the Roadview database of NDOT. The data of crossing structures were also collected from the aerial map pictures and street view pictures when UNR CATER extracting the fencing data.

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Development of Nevada Highway Fencing GIS Database

FINAL REPORT

Prepared for the
SOLARIS Institute
Tier 1 University Transportation Center
and
Nevada Department of Transportation

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August 2019

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DISCLAIMER

SOLARIS PROJECT DTRT13-G-UTC55 and NDOT PROJECT P342-18-803/TO #2

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Dr. Hao Xu, P.E., Assistant Professor of Civil Engineering at UNR, was the Project Principal Investigator. The other author of this report is Yuan Tian, Research Assistant and Ph.D. Candidate at UNR.

ABSTRACT

The Nevada Department of Transportation (NDOT) has been installing wildlife fences along interstate/state highways where wildlife-vehicle collisions (WVCs) concern exists. A fencing geographic information system (GIS) dataset can be used to coordinate the locations and construction of new wildlife crossing structures and wildlife fences. A statewide fencing GIS database is also essential for rural highway safety analysis, especially when it is integrated with crash data, wildlife animal migration data, road properties, and existing crossing structure data. The Center for Advanced Transportation Education and Research (CATER) at the University of Nevada, Reno (UNR) developed a Nevada statewide highway fencing database in this project by reviewing multiple data sources such as Google Earth Pro, Google Maps, Google Street View, Bing Maps and the Roadview database of NDOT. The data of crossing structures were also collected from the aerial map pictures and street view pictures when UNR CATER extracting the fencing data.

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EXECUTIVE SUMMARY

As a solution to wildlife-vehicle collisions (WVCs), wildlife fencing is widely built along highways in rural and suburban areas. Wildlife fencing can improve motorist safety and reduce highways' negative impact on wildlife migration. It is one of the most commonly applied measures to separate wildlife animals and livestock from motorists and is also among the most cost-effective mitigation measures reducing WVCs. The Nevada Department of Transportation (NDOT) deploys install fences along state-maintained highways where WVC concern exists. Although some of the fencing information could be found in project contract documents, a statewide highway fencing GIS data is needed for integrated and accurate fencing information such as locations, fence types, and end types.

A statewide fencing GIS dataset can be compared to the WVC crashes distribution to evaluate the performance of installed fencing and recommend locations of new fencing. Wildlife fencing needs to avoid unintentional effects such as creating an absolute barrier that keeps animals from accessing habitat on the other side of the road. Therefore, the fencing dataset can be used to identify any conflicts between fences and wildlife migration paths. Also, animals are more likely to break through the wildlife fencing if safe crossing opportunities are not well provided, so wildlife fencing is usually combined with safe crossing opportunities, such as wildlife underpasses and overpasses. The fencing GIS dataset can be integrated with data of highway crossing structures to study whether the existing fencing and crossing structures are well coordinated. The statewide fencing GIS dataset is essential for rural highway safety, especially when it is integrated with crash data, wildlife animal migration data, road properties, and existing crossing structure data.

The Center for Advanced Transportation Education and Research (CATER) at the University of Nevada, Reno (UNR) developed a Nevada statewide highway fencing database in this project by reviewing multiple data sources such as Google Earth Pro, Google Maps, Google Street View, Bing Maps and the Roadview database of NDOT. The data of crossing structures were also collected from the aerial map pictures and street view pictures when UNR CATER extracting the fencing data. The fencing information of 5,632-mile NDOT-maintained highways (rural and sub rural areas) was generated. The Interstate highway length is 613 miles; the U.S. route length is 1,966 miles; the state route length is 2,703 miles; the ramp length is 348 miles, and the escape ramp length is 1.2 miles. The fencing data was integrated into a GIS dataset that includes attributes of fencing status (identifiable, no fencing and unidentifiable), fence type, height, post type, ownership, data year, created user, created date, last edited user and last edited date.

CHAPTER 1 BACKGROUND

Wildlife animals crossing highway surface causes a significant amount of crashes. A data study (Huijser, et al., 2007) showed that 725,000 to 1,500,000 wildlife-vehicle collisions happen in the U.S. every year. In a recent five-year span, over 2,000 vehicle-animal crashes were reported in Nevada. Wildlife fencing is one of the most commonly applied measures to separate wildlife from motorists and is also among the most cost-effective mitigation measures reducing wildlife-vehicle collisions (WVCs). Wildlife crossing structures and highway fencing attract the interest of State Departments of Transportation (DOTs) and Departments of Wildlife (DOWs) for the safety of traffic and wildlife animals. The Nevada Department of Transportation (NDOT) has been installing wildlife fences along state-maintained highways where WVC concern exists. "Wildlife Crossing Structure Handbook" (Clevenger, et al., 2011) was published by the Federal Highway Administration (FHWA) in 2011 to provide technical guidelines for the planning, design, and evaluation of wildlife crossing structures and fencing.

Wildlife fencing needs to avoid unintentional effects such as creating an absolute barrier that keeps animals from accessing habitat on the other side of the road. Therefore, detailed and accurate information of wildlife fencing along highways is critical for agencies to identify conflicts between fences and wildlife migration paths. Also, animals are more likely to break through the wildlife fencing if safe crossing opportunities are not well provided, so wildlife fencing is usually combined with crossing structures, such as wildlife underpasses and overpasses. A fencing GIS dataset can be used to coordinate the locations and construction of new wildlife crossing structures and wildlife fences. A statewide fencing GIS database is also essential for rural highway safety analysis, especially when it is integrated with crash data, wildlife animal migration data, road properties, and existing crossing structure data.

There was no wildlife-fencing GIS data available for NDOT, so a wildlife-fencing database is needed by knowing the importance of fencing information. Information of fences that were recently built by NDOT could be found in project documents, although the project plans are often limited by the project scope and can only provide fragmented data. The pdf files or hard copies of the project plans also require significant time for extracting the fencing information. For this reason, the Center for Advanced Transportation Education and Research (CATER) at the University of Nevada, Reno (UNR) developed a Nevada statewide wildlife fencing database in this project by reviewing multiple data sources such as Google Earth Pro, Google Maps, Google Street View, Bing Maps and the Roadview database of NDOT. The data of crossing structures were also be collected using the aerial map pictures and street view pictures when UNR CATER extract the fencing data.

The CATER project team received a GIS map of highways for wildlife-fencing data collection. NDOT do not install or operate fencing along county/city/local roads, the road network for fencing information collection includes only interstate highways (613 miles), U.S. routes (1,966 miles) and state routs (2,703 miles).

This project report is structured as follows: Chapter 2 summarizes highway fencing types that are the essential attribute of the fencing dataset. Chapter 3 introduces the tools and data sources used for fencing data collection and the process of review fencing data with the various software/data tools. Chapter 4 presents statistics of collected fencing data and comparison of the fencing distribution and WVC crashes. Chapter 5 summarized the project effort and achievements.

CHAPTER 2 WILDLIFE FENCE TYPE

The fence type is an essential attribute of the collected wildlife fencing GIS data. This chapter provides a description of the fencing types and materials, which was defined in Wildlife Compatible Fencing published by Arizona Game and Fish Department Mission.

Barbed wire: In large scale livestock applications, barbed wire is the most cost-effective fencing material. Barbed wire consists of 2 twisted strands of 12 ½ gauge galvanized steel wire with a 2-point or more barb pattern spaced 5 inches apart. Generally, these wires are attached to metal T-posts 10-20 feet apart with one or more stays between posts. Barbed wire fences are effective at restraining livestock but can be permeable to most wildlife.

Smooth wire: Smooth wire is a basic design similar to barbed wire but without the barbs. It is generally used in conjunction with other materials or in situations where barbs are not needed.

High tensile wire: High-tensile wire is a single strand of smooth wire. It is used either in combination with other fencing materials, or as the primary barrier in an electric fence. It usually needs low maintenance, but does not provide sufficient deterrent to function as a stand-alone livestock fence unless electrified.

Woven wire: Woven wire is often referred to as “game fence”, “sheep fence”, “hog wire”, or “field fence”. It is composed of multiple strands of horizontal and vertical wire “woven” into a mesh pattern of squares. The woven wire fencing is produced in heights from 2 feet to 8 feet and with a variety of mesh sizes. The size of the openings in the mesh pattern may vary from top to bottom. Typically, the wire is attached to metal t-posts spread 15-20 feet apart. This wire was commonly used in ranching applications where cattle were gathered in smaller spaces and held for short periods of time.

Post and pole (or post and rail): Post and pole fences made from these materials typically use rounded wood rails, attached to vertical wooden posts. These fences are picturesque and are often used in settings where aesthetics is important.

Buck and pole (or jack leg): Buck and pole fences also use rounded wooden rails, but instead of vertical posts uses a triangle of wooden poles (bucks) to provide the vertical structure of the fence. The rails are then attached to the triangle.

Pipe rail fencing: Pipe rail fence is typically composed of small diameter (e.g., ½ inch-1 ½ inch) steel pipe or solid rod rails (e.g. sucker rod) and larger diameter (e.g., 1 ½ inch-2 inch) posts. It is attractive, effective, and low maintenance, but it can be expensive to build. Pipe rail fences are often used to protect small areas of sensitive habitat (e.g., springs or wildlife water developments) from livestock and feral burros, and in areas where wildlife crossings are expected to be frequent. Pipe rail fences can also be used to exclude off-road vehicles.

Electric fencing: There are two main types of electric fences: high tensile wire and braided plastic with a metal strand imbedded (electric rope). Electric fencing can be used as a stand-alone fence or in conjunction with other fence types. In most applications, the fences can be powered by energizers using batteries recharged from solar panels. High-tensile electric wire fences consist of multiple single strands of stainless wires attached to fiberglass posts, or plastic standoffs (insulators) attached to wooden, metal, or plastic posts. The braided electric rope consists of a double helix of metal conductors and plastic filaments braided around a central polypropylene core. The rope can be secured to posts using plastic, glass, or ceramic insulators. Braided electric rope fences are easily installed and make excellent temporary or moveable fences.

CHAPTER 3 SOFTWARE TOOLS AND DATA PROCESSING

3.1 ArcGIS

ArcGIS is a geographic information system (GIS) tool for working with maps and geographic information and was used in this data collection project. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database.

3.2 Bing Maps and Google Maps

Bing Maps and Google Maps provide high-quality traffic maps, satellite/aerial images and 360-degree street view pictures. The two web-based tools (and also data sources) were used for identifying existence and types of wildlife fencing in this project.

3.3 Bing and Google Maps Add-in for ArcMap

The Bing and Google Maps Python Add-in is a GIS plugin tool for ArcGIS. When a user clicks a location on a map in ArcGIS, the plugin tool opens and loads the Bing or Google Maps for that location in a browser. The add-in tool simplify connection of the NDOT GIS road network an Bing & Google Maps that use different geolocation methods. The included map styles are:

- Google Street View
- Google Maps
- Google Satellite
- Google Terrain
- Bing Roads
- Bing Bird's Eye
- Bing Aerial

3.4 Mandli Roadview

NDOT managed a comprehensive state road database and operated with the Mandli Roadview software package including Roadview Workstation, Roadview Explorer and Roadview Player. Roadview Workstation allows users to access all collected data in a synchronized viewing environment. Route information, imaging, GPS, pavement, and LiDAR data can all be accessed through a variety of search and filter tools. Roadview Explorer is an interactive environment that is used for working with roadway images and data using a web browser, and allows users to view images, data, and information through URL access. For basic image viewing, Roadview Player displays single or multiple camera right-of-way images in succession along with corresponding road index data.

3.5 Data review

The steps of collecting wildlife-fencing data along the state-maintained highways is as the following:

Step 1: load the state-maintained road network

There are about 6,322 miles of state-maintained highways (interstate highways, U.S. routes, state routes, ramps and escape ramps of interstate highways) in Nevada. The road network GIS layer was provided by NDOT and loaded into ArcMap at CATER, as shown in Figure 3-1. The project team reviews and extracts wildlife-fencing information segment by segment along the highways. In addition, the urban areas were excluded from fencing extraction because the urban segments of state-maintained highways are normally without wildlife fences.

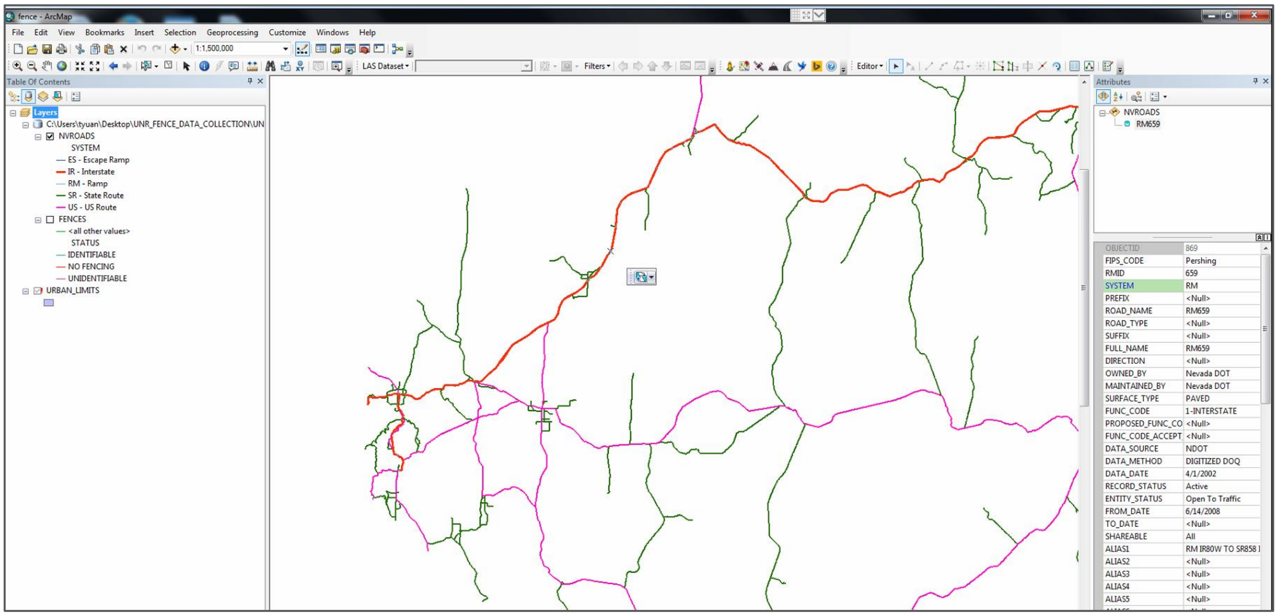

Figure 3-1 Determine the route segment

Step 2: load Google Street View and extract fencing information

The project team loaded the Google Street View by clicking a road segment in ArcMap, and the Bing and Google Maps Add-in automatically opened a browser with the street view interface. By reviewing the 360-degree picture in the Google Street View, as shown in Figure 3-2, the researchers identified the fence information including existence, types, status, and post type, and so on.

Figure 3-2 Google Street View for identifying wildlife fencing information

In the data extraction process, it was found that street view pictures and satellite pictures of most state routes were out of date and with low resolution. For those segments without good-quality street view pictures, the research team accessed the NDOT Roadview database and workstation through an NDOT computer at the NDOT Traffic Safety Engineering. The Roadview includes 120-degree road pictures that are collected by NDOT and updated every few years.

Step 3: draw the fence layer in GIS and input the fence information.

The project team drew the fence lines along the road layer with the editor tool and inputted the fence attributes, as shown in Figure 3-3. Although Google Maps provides the function of measuring distance on a map, the distance between a wildlife fence to its related highway centerline is difficult to measure because the fences are often invisible on a satellite image and the measurement tool is not available for Google Street View. 50-meter default distance between a fence to the centerline was used in this project if the distance could not be measured.

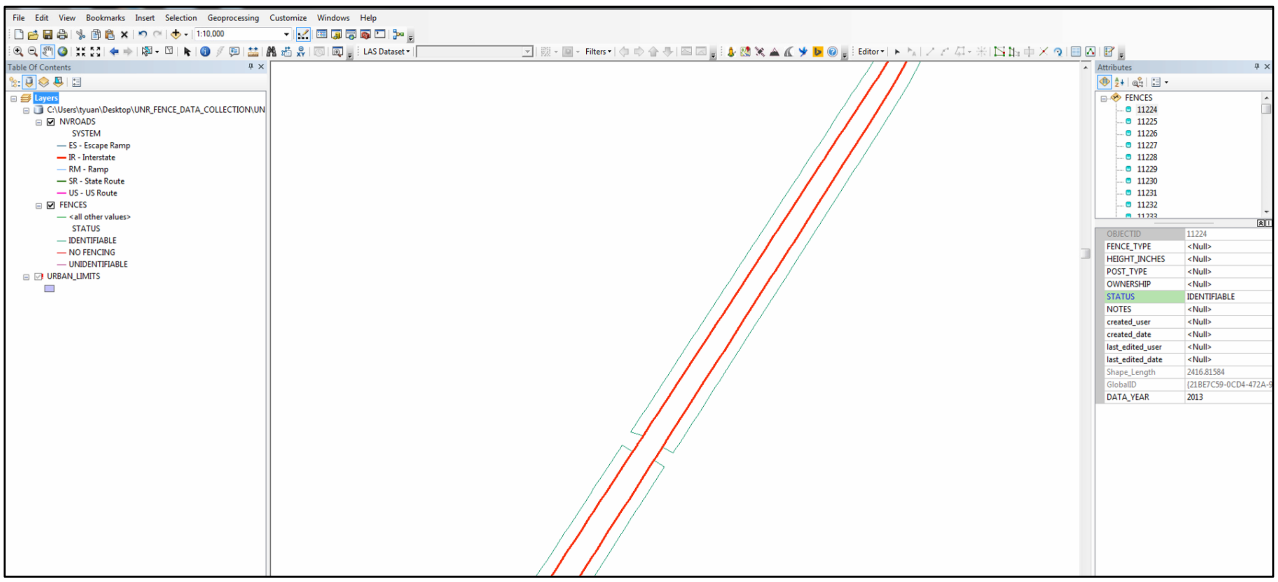

Figure 3-3 Draw the fence and complete the fence information.

The fence layer attributes include:

1) **Status:** input options are identifiable, no fencing, unidentifiable. Identifiable means a wildlife fence can be seen in the street view picture; no fencing means the street view picture or other data source can clearly tell that there is no fence on this segment; unidentifiable is used when the street picture is not clear, and no other data sources can be used to identify whether a fence exists.
2) **Fence type:** input options are 3 wire smooth, 4 wire smooth, 8 wire smooth, 3 wire barbed, 4 wire barbed, 8 wire barbed, bench, cattle pass, chain link, deer, elk, hog, snow, tortoise and other.
3) **Height (inch):** based on the type of fence, the default height information for the fence type was used.
4) **Post type:** input options are metal, T, wood, and others.

5) **Ownership:** Federal, Local, NDOT, private, and others. All the reviewed highways are NDOT-maintained, so the default input for Ownership was NDOT.
6) **Data year:** the year of Google Street View pictures or the NDOT Roadview pictures for extracting fence attributes.
7) **Created user**
8) **Created date**
9) **Last edited user**
10) **Last edited date**

Even with clear street pictures, some of the wildlife fences cannot be seen in the pictures because of the roadside terrain. The project team could locate the cattle grids on the reviewed highways. Between two cattle grids, if fences can be seen along some segments fences were assumed to exist along the segments with roadside terrain blocking street views. By using the Google Street View, NDOT Roadview database and the estimation method based on cattle grids, existence/no existence of fences along the state-maintained highways can be identified. However, it was often difficult to identify fence type and material because of low resolution or quality of some street view pictures.

3.6 Wildlife crossing structures

There are wildlife crossing structures along Nevada highways, especially in Elko County. The crossing structures, including overpasses and underpasses, can be identified in the process of extracting fence data, Figure 3-4.

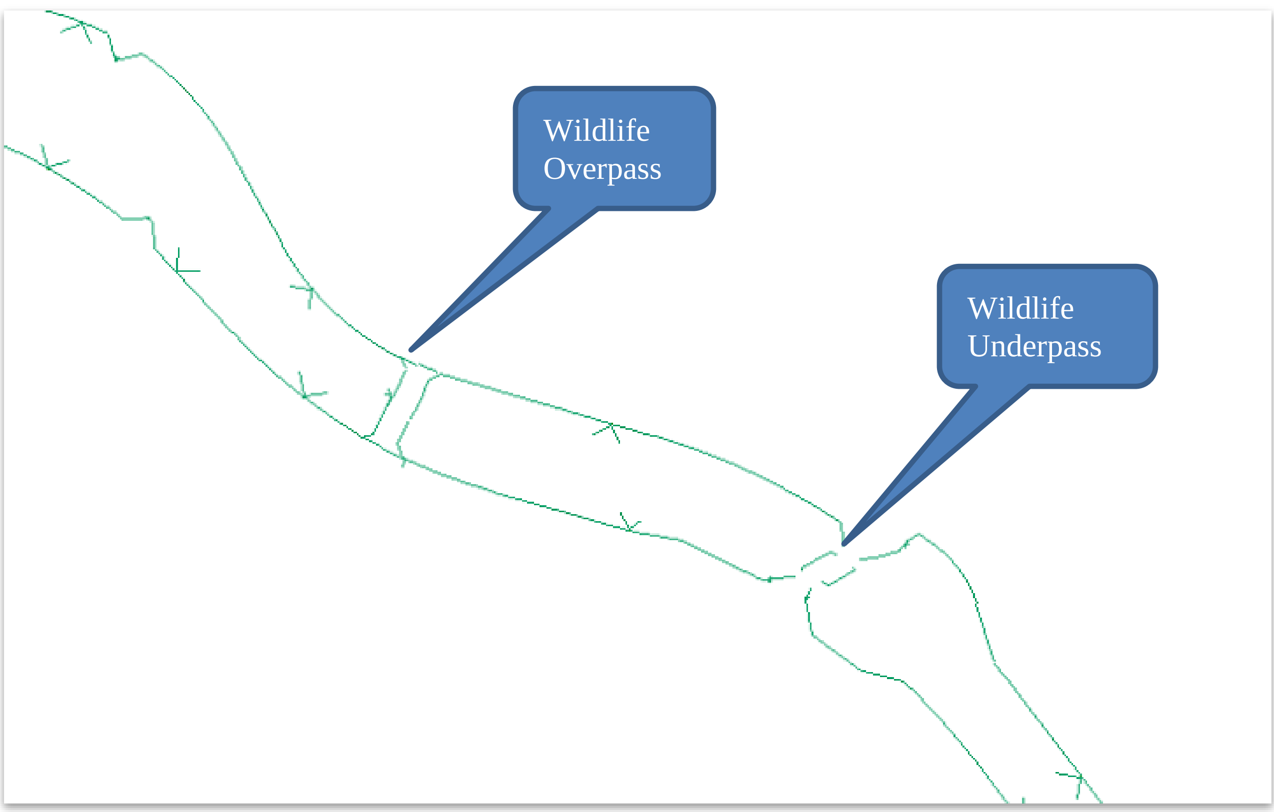

Figure 3-4 Wildlife crossing structures in the fencing GIS layer

CHAPTER 4 DATA ANALYSIS

This section, combined with Nevada's crash dataset, studies fences along different highway classifications on traffic crashes in Nevada. The GIS layer of collected fencing data is shown in Figure 4-1.

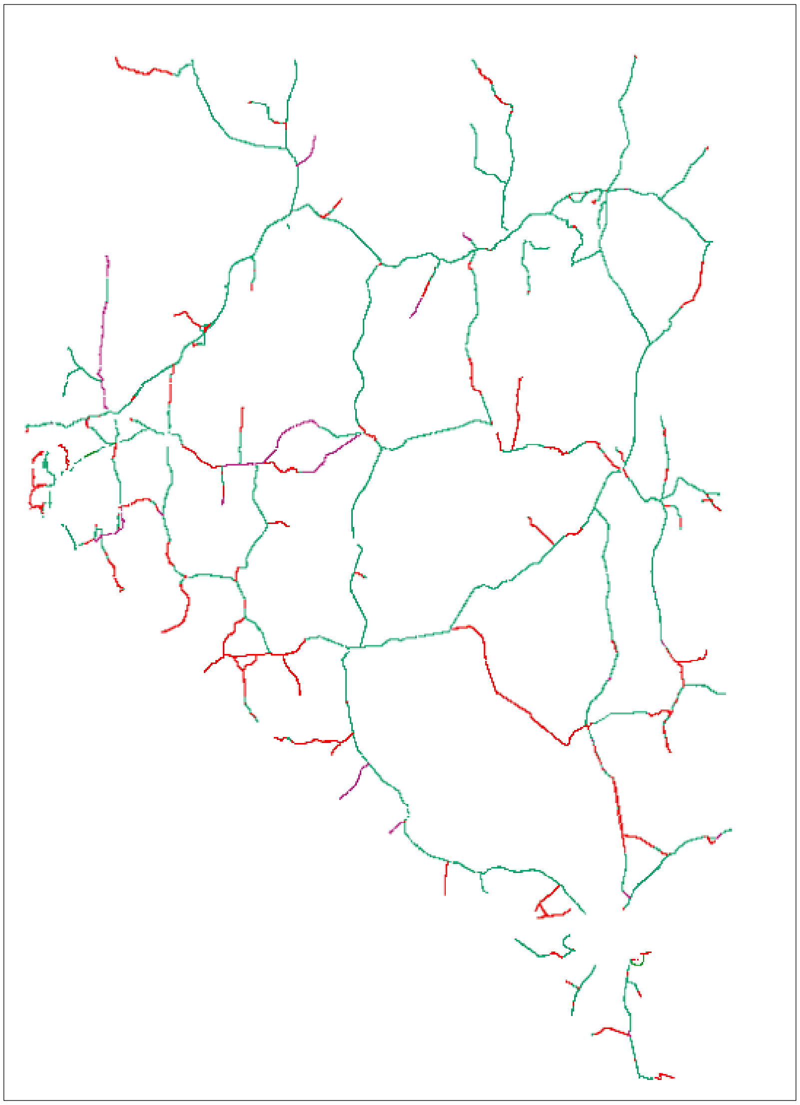

Figure 4-1 Fencing along NDOT-Maintained highways (Green - identifiable fencing; red - no fencing; purple - unidentifiable)

The total state-maintained highway length is 5,632 miles in Nevada (rural and sub rural area) and the distribution related to highway classifications is shown in Figure 4-2. The Interstate highway length is 613 miles; the U.S. route length is 1,966 miles; the state route length is 2,703 miles; the ramp length is 348 miles, and the escape ramp length is 1.2 miles.

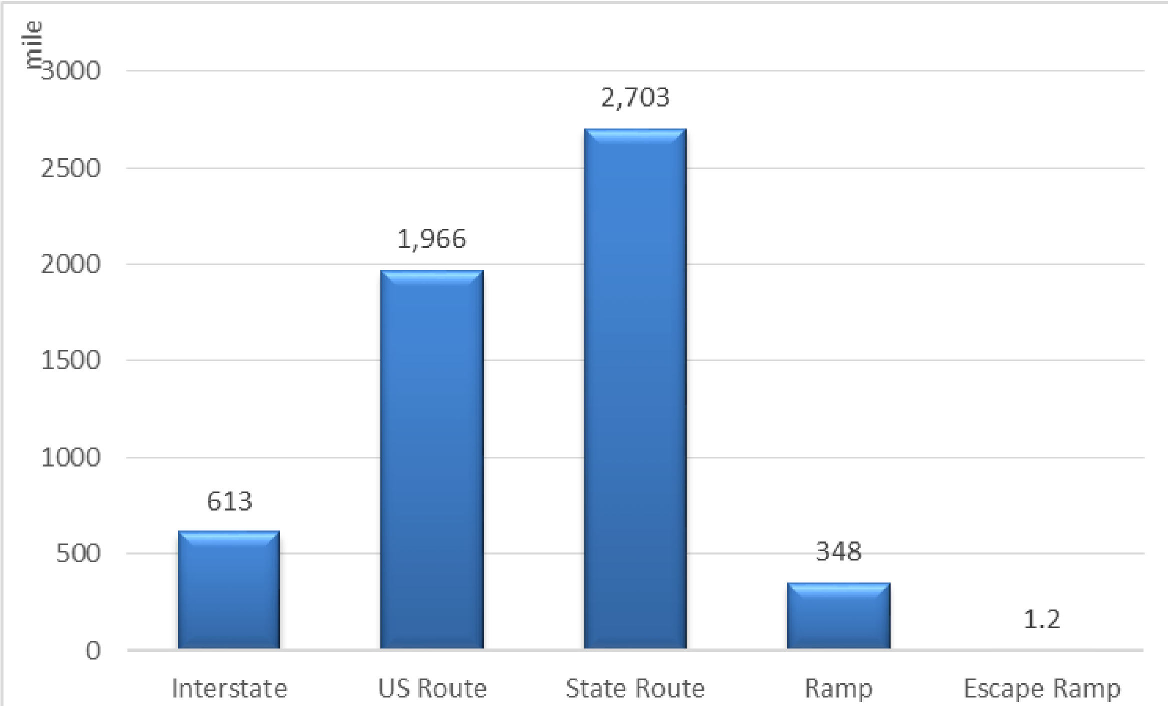

Figure 4-2 Lengths of different NDOT-maintained highways with fencing

In all the NDOT maintained highways, 67% are with fencing in the rural and suburban areas in Nevada; 27% are no fencing; and 6% are unidentifiable with the existing street view data from Google, Bing or NDOT Roadview. The data is presented in Figure 4-3.

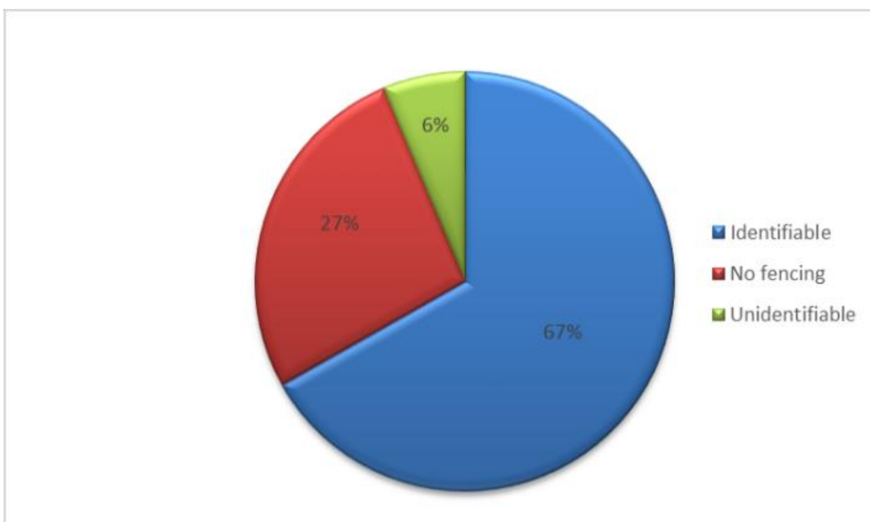

Figure 4-3 Lengths and percentages of NDOT-maintained highways with and without fencing

Almost all the interstate highways in Nevada are with fencing, and the lengths of state routes with fencing and U.S. routes with fencing are demonstrated in Figure 4-4 and Figure 4-5. For the State route, 52% of the state routes are equipped with fence, and 39% of them are without fence. While for US route in Nevada, 77% of them are equipped with fence and 19% of them are without fence.

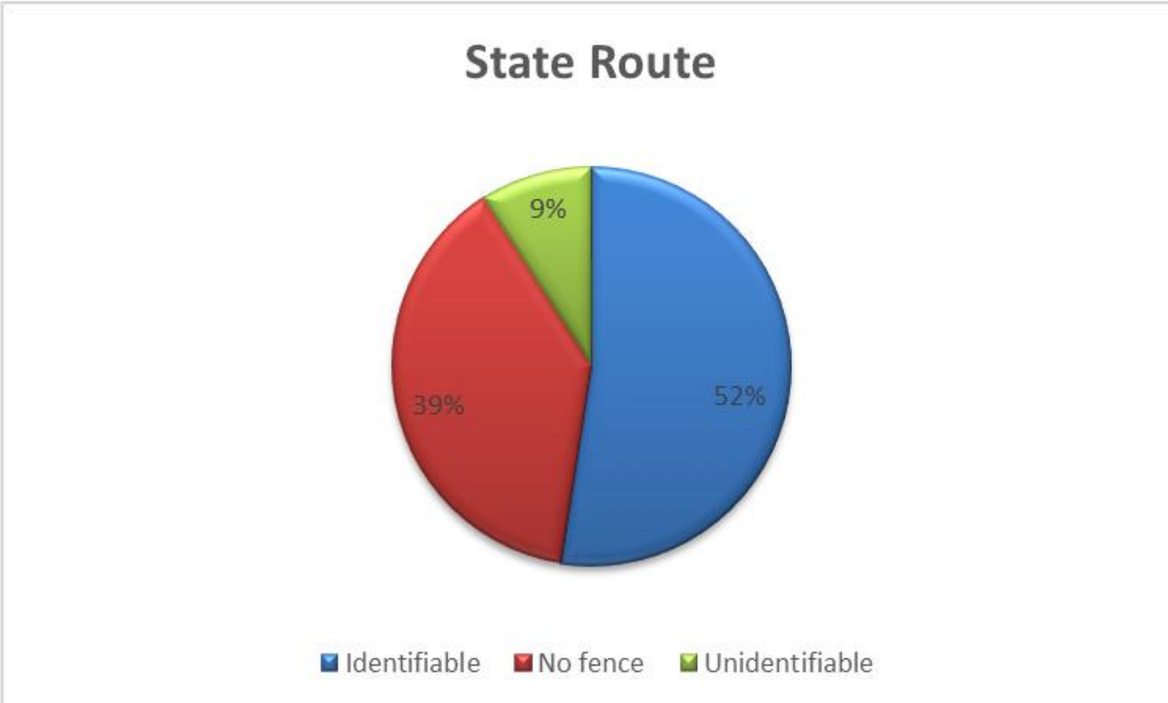

Figure 4-4 Percentages of state routes with and without fencing

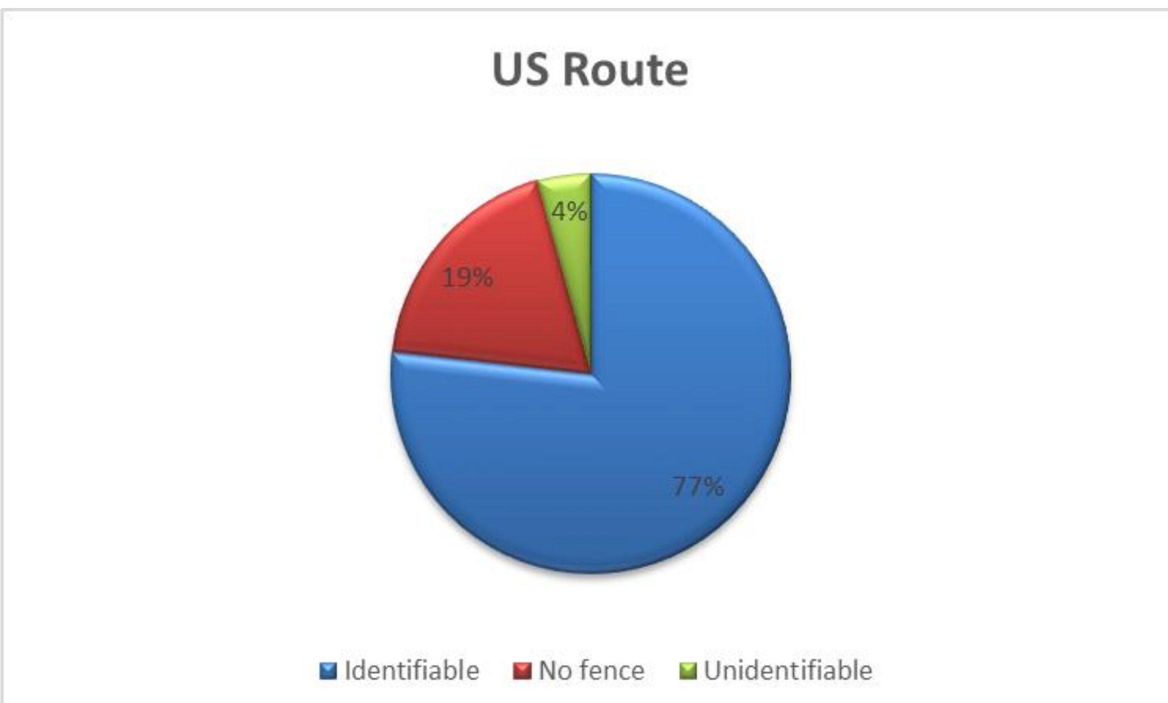

Figure 4-5 Percentages of U.S. routes with and without fencing

4.1 WVC crash frequencies

From 2008 to 2017, the total WVC crashes are 3,968(rural). Among them, 2,865 WVCs occurred on the highway segments with fencing, and 1,103 WVCs occurred on highways without fencing, as shown in 4-6. The average number of WVC crashes on highways with fencing was 0.983 WVC crashes per mile, while the average number of WVC crashes on highways without fencing was 0.941 WVC crashes per mile. Figure 4-7 shows the change in WVC crashes from 2006 to 2017. The WVC crashes in Nevada decreased in 2013 through 2015 but increased in 2016 and 2017 especially crashes on highways without fencing. Figure 4-8 illuminates the numbers of WVC crashes in each county of Nevada. Lincoln and Elko had the highest numbers of WVC crashes in 2008-2017, and Lincoln's WVC crashes on highways without fencing were significantly higher than other counties and the state average.

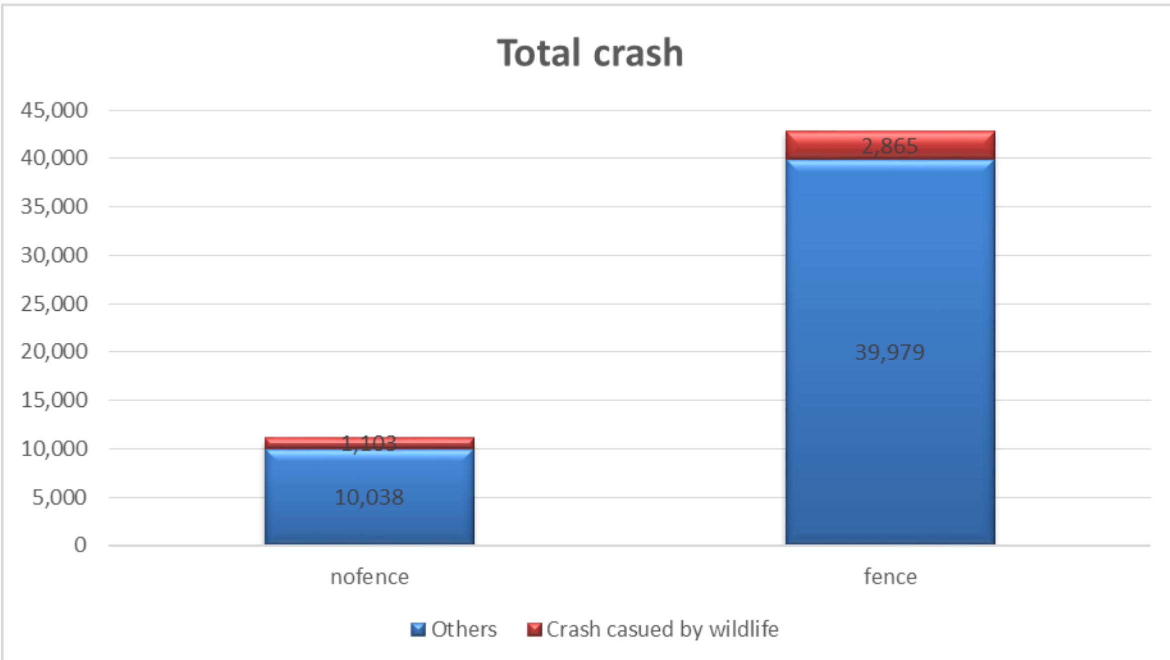

Figure 4-6 Wildlife-vehicle crashes on highways with and without fencing.

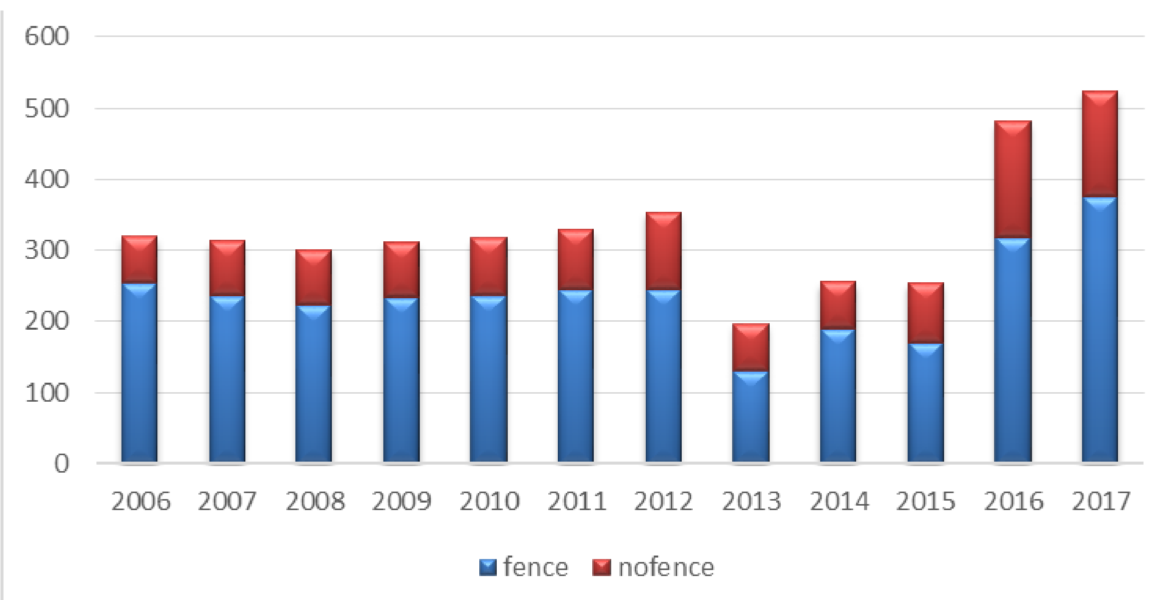

Figure 4-7 Annual WVC crashes on highways with and without fencing

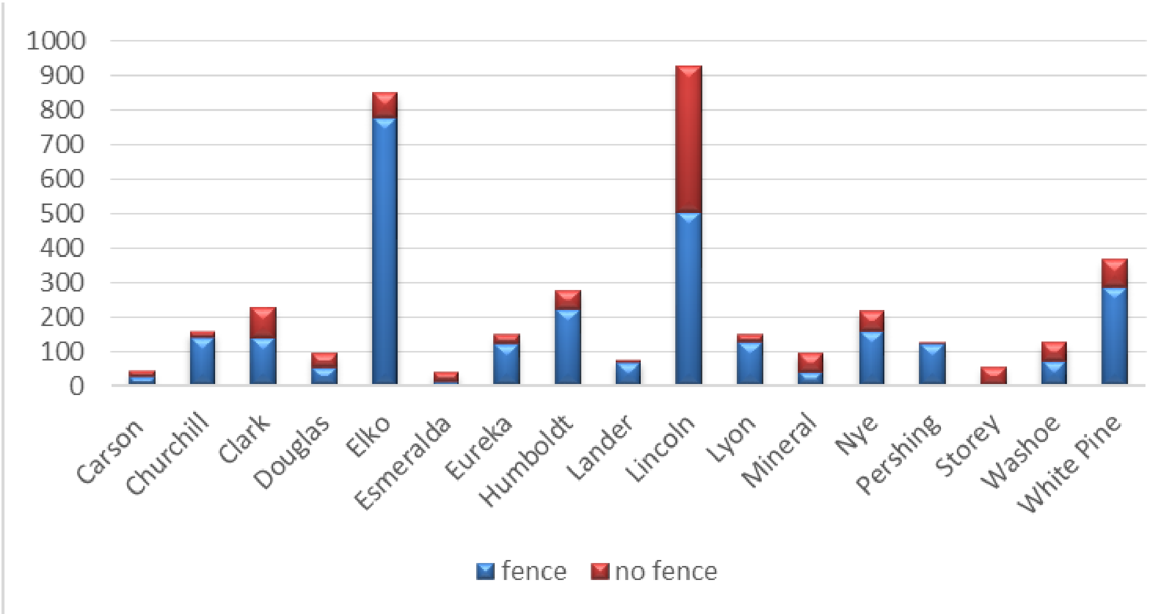

Figure 4-8 WVC crashes in counties Nevada

It needs to be noted that the higher number of WVC crashes on highways with fencing does not mean highways with fencing are more dangerous for drivers and wildlife animals. Highways with fencing are normally in the areas with high-frequency wildlife crossing and fences were normally installed along the highways with WVC safety concerns.

4.2 Wildlife body removable data

The actual number of WVCs is often higher than the reported crashes, as it is assumed only parts of such collisions are reported to authorities. The NDOT's wildlife body removal data can provide extra information about conflicts between wildlife animals and vehicles on highways. The wildlife body removal dataset was created by NDOT District engineers or contractors. A record is created and input when an animal body was seen on the highway. The project team received the dataset from NDOT for the time period of 2004 to 2019. In order to coordinate with the crash dataset, the project team selected the data from 2006 to 2017, Figure 4-9.

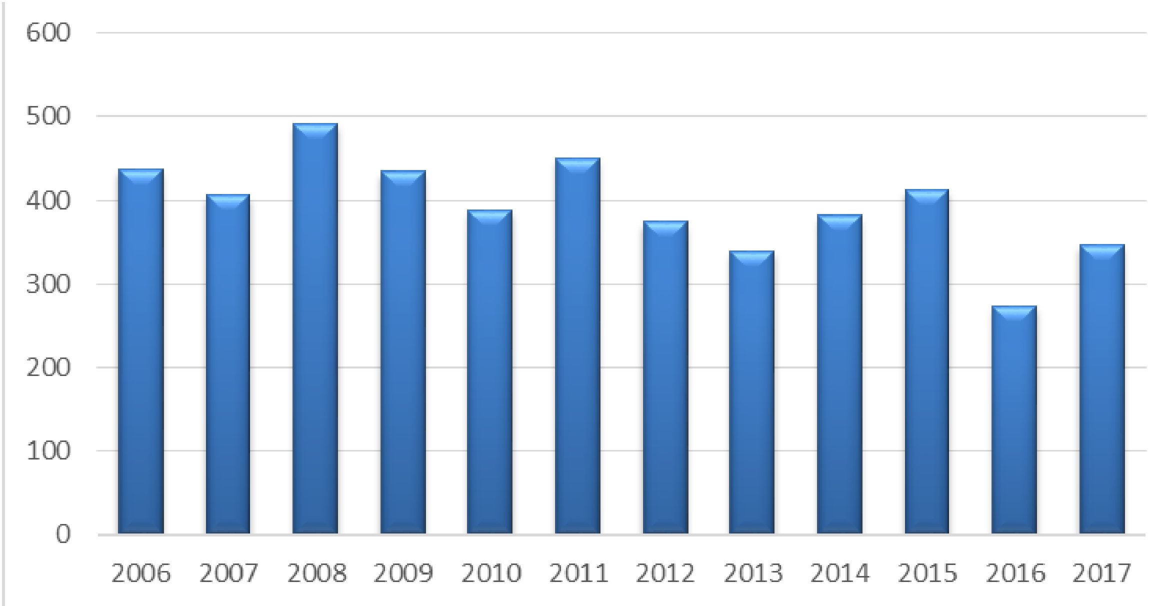

Figure 4-9 Annual number of wildlife body removal 2006-2017 in Nevada

Figure 4-10 shows the number of wildlife body removal in 2006-2017 in each county. Elko had much more animal bodies found and removed from highways than other counties. Figure 4-11 shows the numbers of wildlife body removal on different classifications of highways. The average number of the dead wildlife body removal for the Interstate Highways is 2.29 /mile while the average dead wildlife body removal for the U.S. routes is 0.75 /mi and the average dead wildlife body removal for the State routes is 0.68 /mi.

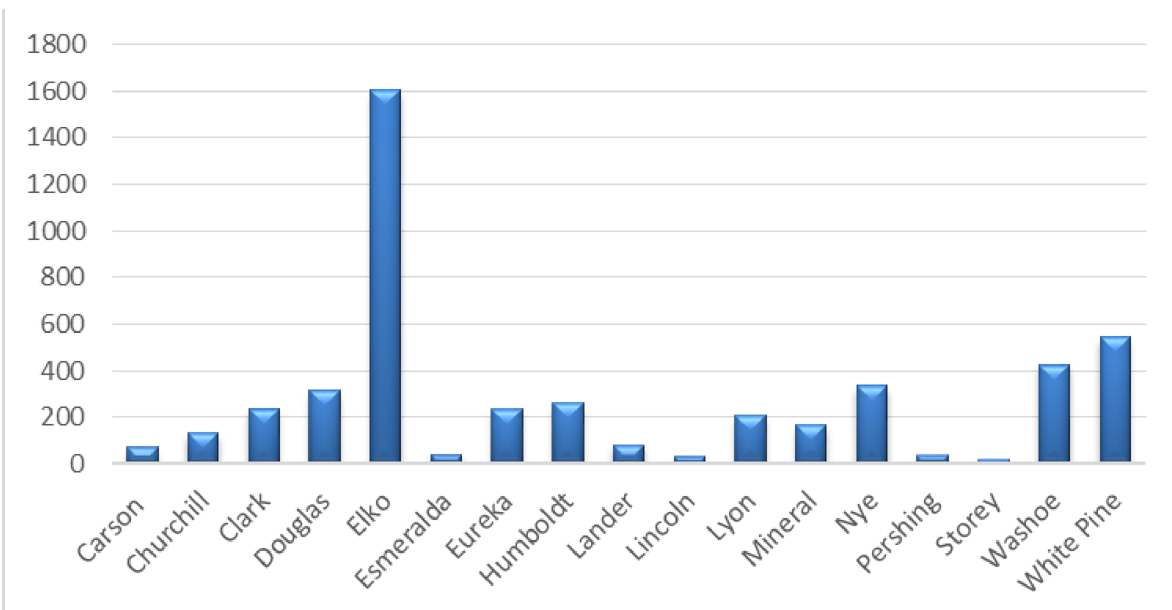

Figure 4-70 Wildlife body removal in counties of Nevada 2006-2017

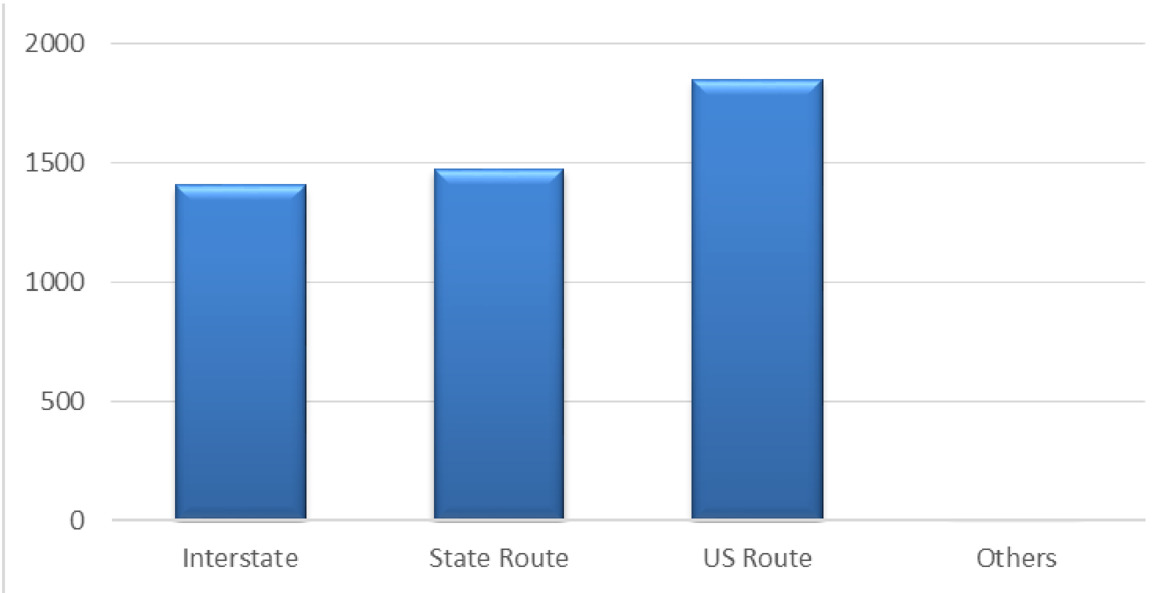

Figure 4-11 Wildlife body removal of different highway classifications

In Figure 4-12, the majority (73%) of all removed animal bodies were deer. Besides deer, more cows, horse, elk and burro bodies were found on highways.

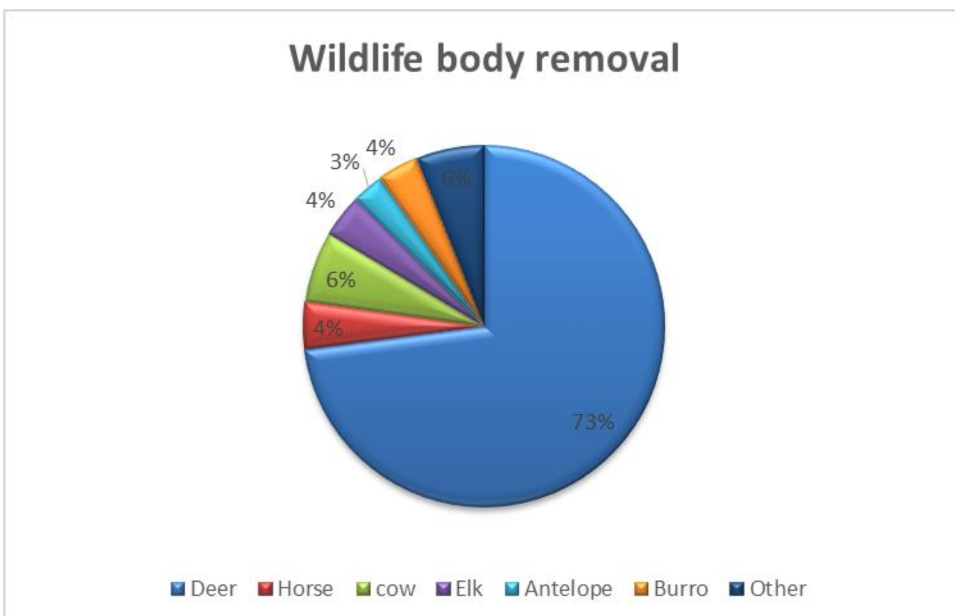

Figure 4-8 Species of wildlife body removal

CHAPTER 5 SUMMARY

The CATER team completed the following tasks in this project:

1) Collection of fencing and crossing facilities data
2) Development of the NDOT-maintained highway fencing GIS database
3) Integration of fencing data, crossing structure data, historical crash data, and the road network data

With the tools of ArcGIS, Google Street View, and NDOT Roadview, CATER created a fencing GIS database for all NDOT-maintained highways in rural and suburban areas in Nevada. Fencing information of 5,632-mile highways was reviewed and stored in the database, including 67% highways with fencing, 27% without fencing and 6% unidentifiable highways where current street view pictures could not tell whether fencing existed. The fencing database includes attributes of fencing status (identifiable, no fencing and unidentifiable), fence type, height, post type, ownership, data year, created user, created date, last edited user and last edited date.

Date analysis was performed to study crash distribution on highways with and without fencing. Although the average WVC crashes on highways with fencing was a little bit higher than highways without fencing in 2006-2017, it should not be interpreted as highways with fencing are more dangerous. Fences were installed along highways with more animals crossing roads and with major WVC safety concerns. A study of before-after WVC crash comparison for highway fencing can provide more comprehensive information of fencing's influence on highway safety. The wildlife body removal dataset created by NDOT District engineers was also studied to understand non-reported wildlife-vehicle conflicts on state highways.

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