Potential Mitigation Measures Aimed at Reducing Collisions and Improving Habitat Connectivity for Louisiana Black Bear in and Around Tensas River National Wildlife Refuge and Bayou Teche National Wildlife Refuge, Louisiana, USA

by

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FINAL REPORT

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<td>Between 2011 and 2014, 20-35 Louisiana black bear (<em>Ursus americanus luteolus</em>) road-kills were recorded annually out of an estimated population of 500-750 individuals. Louisiana black bear were mostly road-killed along the west bank of the Mississippi River. We especially evaluated black bear road mortality data along three road sections in and around Tensas River National Wildlife Refuge and Bayou Teche National Wildlife Refuge: I-20 and U.S. Hwy 65 near Tensas River NWR and U.S. Hwy 90 near Bayou Teche NWR. The highest densities of black bear road-kills occurred along US Hwy 90 near Bayou Teche NWR, near Patterson and Morgan City. If mitigation measures for Louisiana black bear are implemented, we suggest prioritizing road sections where the black bear will have the highest probability of connecting to other existing populations or potential suitable habitat patches, effectively connecting the black bear population in and around Tensas River NWR with the one in and around Bayou Teche NWR. Connectivity for black bears, including through safe crossing opportunities across highways, is likely most beneficial along the west side Mississippi, outside of the floodplain, as the bears have limited use of the floodplains and the existing bridges for highways in low and wet areas. This means that the safe crossing opportunities (underpasses and potentially also overpasses) cannot necessarily be combined with existing crossing structures, especially not structures that are primarily designed for rivers and streams. Instead, we recommend adding new designated crossing structures and fences that are specifically designed for black bear in dry areas. Installing fences and providing safe crossing opportunities along highways in the southern area of the Habitat Restoration Planning Area (HRPA) (i.e. I-10 between Lafayette and Baton Rouge), and US Hwy 90 between New Iberia and Morgan City) is critical.</td>
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SUMMARY

The Tensas River NWR and Bayou Teche NWR and surrounding areas host two of the three core populations of the Louisiana black bear (*Ursus americanus luteolus*). Even though the Louisiana black bear was delisted during the course of this project, direct mortality as a result of vehicles hitting the animals is known to be among the major threats to the continued existence of this subspecies. Between 2011 and 2014, 20-35 black bear road-kills were reported annually out of an estimated population of 500-750 individuals. The US Fish and Wildlife Service (USF&WS) and the Louisiana Department of Wildlife and Fisheries have expressed concern about direct road mortality and habitat connectivity for the Louisiana black bear across highways, especially on and along I-20, U.S. Hwy 65 near Tensas River NWR and U.S. Hwy 90 near Bayou Teche NWR.

Louisiana black bear were mostly road-killed along the west bank of the Mississippi River. The highest densities of black bear road-kills occurred along US Hwy 90 near Bayou Teche NWR, near Patterson and Morgan City. The highest densities of large wild mammal crashes occurred along I-20 near Tensas River NWR, between Monroe and east of Delhi. Note that the locations where most black bear are hit are not the same as the locations where most large wild mammals are hit, as the latter is dominated by white-tailed deer.

We conducted cost-benefit analyses for four different types and combinations of mitigation measures based on the large wild mammal collisions and estimated carcass counts for the three highway sections. The analyses were mostly based on human safety parameters and did not include passive use values for wildlife. There was not a single road section where the costs associated with large wild mammal-vehicle collisions reached or exceeded the thresholds of four different mitigation packages. Therefore, if mitigation measures are implemented, the justification cannot only be based on cost parameters related to human safety. The value of wildlife, including passive use values, needs to be part of the justification.

If mitigation measures for Louisiana black bear are implemented, we suggest prioritizing the road sections where the black bear will have the highest probability of connecting to other existing populations or potential suitable habitat patches. This would eventually effectively connect the black bear population in and around Tensas River NWR with the one in and around Bayou Teche NWR. This would result in a larger effective population in a network of habitat patches, safe corridors between the habitat patches, and ultimately reduced probability of regional extirpation. Note that the southern population in and around Bayou Teche NWR is smaller, and still effectively isolated from the populations further north, including those in and around Tensas River NWR. The southern black bear population in and around Bayou Teche NWR has most to gain from measures aimed at restoring habitat connectivity to the populations further north.

Connectivity for black bears, including through safe crossing opportunities across highways, is likely most beneficial along the west side Mississippi, outside of the floodplain as the black bears have limited use of the floodplains and the existing bridges for highways in low and wet areas. This means that the safe crossing opportunities (underpasses and potentially also overpasses) cannot necessarily be combined with existing crossing structures, especially not structures that are primarily designed for rivers and streams. Instead, we recommend adding new designated
crossing structures that are specifically designed for black bear in dry areas, especially along highways in the Louisiana black bear Habitat Restoration Planning Area (HRPA). Providing safe crossing opportunities along highways in the southern area of the HRPA (i.e. I-10 between Lafayette and Baton Rouge, and US Hwy 90 between New Iberia and Morgan City) is critical. Currently, the vast majority of the black bears in and around Bayou Teche NWR are south of US Hwy 90. To connect the black bear in and around Tensas River NWR to the ones north of I-20 and Arkansas, connectivity across I-20 is required. The section of I-20 between Delhi and Tallulah also has a relatively high incidence of black bear road mortality which would be mitigated at the same time.

If the objectives are to reduce direct road mortality of black bear and to reduce the barrier effect of highways, we recommend wildlife fences in combination with wildlife underpasses and overpasses. The fences and crossing structures need to be specifically designed for black bear. Black bear can climb trees, and they can also climb wooden fences posts. Therefore, we recommend smooth metal posts rather than wooded. Furthermore, we recommend tall fences (e.g. 10 ft high) and an overhang or lip facing away from the road. The fence material must be tough and able to resist teeth and claws, and the mesh size should be small enough so that black bear cannot put their feet in a mesh and climb a fence. Chain-link fence material seems to be the best choice for black bear. The fence material should be attached to the safe side of the fence; not to the road side. Because bears can dig, a dig barrier (or apron) (3 ft) attached to the fence, angled away from the road is also recommended. Access roads and fence ends on the main highway should not be access points for black bear into the fenced road corridor. While wildlife guards (modified cattle guards) are a substantial barrier for large ungulates, they are not a barrier for black bear. For black bear, electric mats or electric concrete are recommended. Jump-outs or escape ramps (for deer about 5-5.5 ft high) allow animals to escape from the fenced road corridor. Jump-outs should be high enough so that animals do not readily jump into the fenced road corridor. At the same time, they should be low enough so that animals will readily jump down to the safe side of the fence. For black bear a metal face on the jump-out may be helpful as this makes it more difficult for them to climb up into the fenced road corridor.

We recommend designated crossing structures for black bear, especially long bridges and large mammal underpasses. However, care must be taken that the structures have a bottom that is level with the surrounding area and that they are not flooded for long periods. Based on wildlife camera data at existing bridges across rivers and streams and discussions with Louisiana black bear experts in the region, it is important that designated structures under highways are constructed in relatively dry areas. Solely relying on existing structures primarily built for other purposes is unlikely to result in substantial connectivity. However, it is advisable to tie the wildlife fences into existing structures to maximize their potential as wildlife crossing structure, despite their limited expected use by black bear.
1. INTRODUCTION

1.1. Background

The Tensas River National Wildlife Refuge (Tensas River NWR) is located in northeast Louisiana (Figure 1, 2) and the Bayou Teche National Wildlife Refuge (Bayou Teche NWR) is located in southeast Louisiana (Figure 1, 3). The Tensas River NWR, about 80,000 acres in size, is characterized by bottomland hardwood forests and oxbow lakes. The dominant land use outside the refuge is agriculture. In addition, there are two major transportation corridors near the refuge: I-20 to the north of the refuge (a four-lane interstate running east-west between Monroe (LA) and Jackson (MS), and U.S. Hwy 65 to the east of the refuge (a two-lane highway running north-south between Tallulah and Clayton). Bayou Teche NWR is a complex of habitat fragments totaling about 9,028 acres in size with bottomland hardwoods and cypress-gum forests in the southern Atchafalaya River Basin. The areas outside the refuge include other (semi-) natural habitat, agriculture and small towns (Figure 3). In addition, U.S. Hwy 90 (a four-lane highway with a median between New Orleans and Lafayette) splits some of the habitat fragments.

Figure 1: The approximate locations of Tensas River NWR and Bayou Teche NWR, Louisiana, USA.
Figure 2: The Tensas River NWR and I-20 and U.S. Hwy 65, Louisiana, USA.

Figure 3: The Bayou Teche NWR and U.S. Hwy 90, Louisiana, USA.
The Tensas River NWR and the Bayou Teche NWR and surrounding areas host two of the three core populations of the Louisiana black bear (*Ursus americanus luteolus*) (Department of Wildlife and Fisheries, 2015). The Louisiana black bear suffered from habitat loss and was listed as an Endangered and Threatened Species in 1992 (USF&WS, 2017). Protection and habitat restoration resulted in an increase in population size over the last few decades. The population is now estimated at 500-750 Louisiana black bears, about twice the number when the subspecies was listed (USF&WS, 2017). Eventhough the Louisiana black bear was delisted during the course of this project (10 March 2016 (USF&WS, 2017)), direct mortality as a result of vehicles hitting the animals is known to be among the major threats to the continued existence of this subspecies (Huijser et al., 2008). The US Fish and Wildlife Service (USF&WS) (Pers. com. Jo Ann Clark and Kelly Purkey, USF&WS) and the Louisiana Department of Wildlife and Fisheries have expressed concern about direct road mortality of and habitat connectivity for the Louisiana black bear on and along I-20, U.S. Hwy 65 near Tensas River NWR and U.S. Hwy 90 near Bayou Teche NWR.

I-20 and U.S. Hwy 65 near Tensas River NWR have several existing bridges and culverts across rivers and old oxbows. There is currently no wildlife fencing associated with these bridges and culverts. Some of the existing bridges and culverts have been monitored for wildlife use with wildlife cameras, though only about 3 months of data were available as cameras had to be removed during periods with high water. Based on the limited data that were available, the number of black bears that use the existing bridges and culverts is thought to be very low. As the right-of-way fencing was scheduled to be replaced, the USF&WS has suggested to the Louisiana Department of Transportation and Development (DOTD) to install bear-resistant fencing along I-20 north of the refuge. U.S. Hwy 90 near Bayou Teche NWR has several existing bridges across canals that may or may not be suitable for wildlife.

### 1.2. Goal of the Project

The goal of this project is to explore the options for potential future mitigation measures aimed at:

1. Reducing direct road mortality of Louisiana black bears along I-20 and U.S. Hwy 65 near Tensas River NWR and U.S. Hwy 90 near Bayou Teche NWR.

At the same time, the potential future mitigation measures should:

1. Improve human safety through reducing wildlife-vehicle collisions, specifically with large mammals (e.g. black bears, white-tailed deer (*Odocoileus virginianus*)).
2. Not increase the barrier effect of I-20, U.S. Hwy 65 and U.S. Hwy 90 for other species in the area, regardless of their size and regardless of whether they are considered a concern for human safety.
This report focuses on the following highway sections:
- I-20, about 20 miles in length north of Tensas River NWR.
- U.S. Hwy 65, about 20 miles in length east of Tensas River NWR.
- U.S. Hwy 90, about 20 miles in length through different fragments of the Bayou Teche NWR.

1.3. Tasks

Task 1. Request information.
a. Request existing crash and carcass data for the three road sections described above from the Louisiana Department of Wildlife & Fisheries, and the Louisiana Department of Transportation and Development.
b. Request coordinates for the mile markers along I-20, U.S. Hwy 65, and U.S. Hwy 90. This allows for the plotting of the crash and carcass data.
c. Request (summarized) data on wildlife using existing culverts and bridges along I-20 and U.S. Hwy 65.

Task 2. Analyze the crash and carcass data to identify and prioritize road sections that may have a concentration of wildlife-vehicle collisions, specifically with Louisiana black bear.

Task 3. Conduct cost-benefit analyses for selected mitigation measures (including wildlife fences and wildlife crossing structures) aimed at reducing collisions with large mammals and providing safe crossing opportunities for large mammals.

Task 4. Conduct a site visit, conduct interviews with stakeholders (concerns, perspectives on the problem(s) and suggested mitigation measures), and discuss preliminary results and suggestions with representatives of US Fish & Wildlife Service, Louisiana Department of Wildlife & Fisheries, and the Louisiana Department of Transportation and Development.

Task 5. Suggest options for mitigation measures.

Task 6. Deliver a final report.
2. BLACK BEAR ROADKILL OBSERVATIONS

2.1. Black Bear Roadkill Data

The USF&WS provided records for road-killed Louisiana black bear (n=252) between 1988 and 24 Aug 2015 (though some records did not include an observation or kill date or year) (Data provided by Robert Greco, Louisiana Ecological Services, U.S. Fish & Wildlife Service).

2.2. Trend and Gender

The number of road-killed bears increased substantially from 2007 onwards (note that 2015 was an incomplete year) (Figure 4). Of the 190 road-killed Louisiana black bears with known gender, 54.2% was male and 45.8% was female. Between 2011 and 2014 20-35 black bear road-kills were reported each year.

Figure 4: Number of road-killed Louisiana black bears (n=252) between 1988 and 24 August 2015 around Tensas River NWR and Bayou Teche NWR, Louisiana, USA.
2.3. **Black Bear-Vehicle Collision Locations**

Louisiana black bear were mostly road-killed along the west bank of the Mississippi River (Figure 5).

![Map of Louisiana showing road-killed black bear locations](image)

*Figure 5: Locations of road-killed Louisiana black bear (red dots) in and around Tensas River NWR and Bayou Teche NWR, Louisiana, USA.*
Near Tensas River NWR, most of the observations of road-killed Louisiana black bears were along I-20 between Rayville and Vicksburg and along U.S. Hwy 65 south of Tallulah (Figure 6).

Figure 6: Locations of road-killed Louisiana black bear (red dots) in and around Tensas River NWR, Louisiana, USA.
Near Bayou Teche NWR, most of the observations of road-killed Louisiana black bears were along U.S. Hwy 90 between Baldwin and Morgan City (Figure 7).

Figure 7: Locations of road-killed Louisiana black bear (red dots) in and around Bayou Teche NWR, Louisiana, USA.
2.4. **Black Bear-Vehicle Collision Hotspots**

For the hotspot analyses we used all available black-bear-vehicle collision data. We conducted a Kernel density analysis using ArcGIS 10.6.1 (ESRI, 2018) for point features of black bear-vehicle collision locations using a 25 m cell size (82 ft x 82 ft). A 25 m cell size is relatively fine scale and accommodates for some spatial inaccuracies in GPS coordinates. The Kernel density analysis calculates the density of road-kills in a neighborhood around each cell and based on the quartic kernel function described in Silverman (1986). Consistent with Gomes et al. (2009) we set the neighborhood search radius at 500 m. On a straight road this basically means that black bear roadkill that are up to about 0.3 mi (500 m) away are included in the density analyses for each cell.

We displayed the results as heat maps showing varying densities of black bear-vehicle collisions (Figure 8-11). We used 5 percentage breaks (<5%, 5-24.9%, 25-49.9%, 50-74.9%, and 75-100%) that display the areas with the highest densities of black bear-vehicle collisions (<5%) to areas with the lowest densities (75-100%). The highest densities occurred along US Hwy 90 near Bayou Teche NWR, near Patterson and Morgan City (Figure 11).

![Figure 8: Kernel density hotspot map using percentiles for black bear-vehicle collisions along I-20 in and around Tensas River NWR, Louisiana, USA.](image-url)
Figure 9: Kernel density hotspot map using percentiles for black bear-vehicle collisions along I-20 and US Hwy 65 in and around Tensas River NWR, Louisiana, USA.
Figure 10: Kernel density hotspot map using percentiles for black bear-vehicle collisions along US Hwy 65 in and around Tensas River NWR, Louisiana, USA.
Figure 11: Kernel density hotspot map using percentiles for black bear-vehicle collisions along US Hwy 90 in and around Bayou Teche NWR, Louisiana, USA.
3. LARGE WILD MAMMAL CRASHES

3.1. Animal Crash Data

Animal-vehicle crash data were obtained for three highway sections spanning 10 years (1 January 2005 through 31 December 2014) (Data provided by Bryan Costello, Highway Safety, Louisiana Department of Transportation and Development (Louisiana DOTD). The highway sections were:

- I-20 between mile reference points 116.151 and 189.535 (73.4 mi).
- US Hwy 65 between mile reference points 38.013 and 56.366 (18.4 mi).
- US Hwy 90 between mile reference points 129.788 and 175.269 (45.5 mi).

We selected crashes with large wild animal species only (larger than coyote) (Table 1).

Table 1: The large wild animal species included for our analyses.

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<tr>
<th>Species</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-tailed deer (<em>Odocoileus virginianus</em>)</td>
<td>77</td>
<td>80.21</td>
</tr>
<tr>
<td>Black bear (<em>Ursus americanus luteolus</em>)</td>
<td>17</td>
<td>17.71</td>
</tr>
<tr>
<td>White-tailed deer?</td>
<td>1</td>
<td>1.04</td>
</tr>
<tr>
<td>Black bear?</td>
<td>1</td>
<td>1.04</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>100.00</td>
</tr>
</tbody>
</table>

3.2. Hotspots

For the hotspot analyses we used all available large wild animal-crash data. We conducted a Kernel density analysis using ArcGIS 10.6.1 (ESRI, 2018) for point features of large wild animal-crash locations using a 25 m cell size (82 ft x 82 ft). A 25 m cell size is relatively fine scale and accommodates for some spatial inaccuracies in GPS coordinates. The Kernel density analysis calculates the density of roadkills in a neighborhood around each cell and based on the quartic kernel function described in Silverman (1986). Consistent with Gomes et al. (2009) we set the neighborhood search radius at 500 m. On a straight road this basically means that large wild animal-crash locations that are up to about 0.3 mi (500 m) away are included in the density analyses for each cell.

We displayed the results as heat maps showing varying densities of large wild animal-crash locations (Figure 12-15). We used 5 percentage breaks (<5%, 5-24.9%, 25-49.9%, 50-74.9%, and 75-100%) that display the areas with the highest densities of large wild animal-crash locations (<5%) to areas with the lowest densities (75-100%). The highest densities occurred
along I-20 near Tensas River NWR, between Monroe and east of Delhi (Figure 12). Note that the locations where most black bear are hit are not the same as the locations where most large wild mammals are hit as the latter is dominated by white-tailed deer.

Figure 12: Kernel density hotspot map using percentiles for large wild mammal crashes along I-20 in and around Tensas River NWR, Louisiana, USA.
Figure 13: Kernel density hotspot map using percentiles for large wild mammal crashes along I-20 and US Hwy 65 in and around Tensas River NWR, Louisiana, USA.
Figure 14: Kernel density hotspot map using percentiles for large wild mammal crashes along US Hwy 65 in and around Tensas River NWR, Louisiana, USA.
Figure 15: Kernel density hotspot map using percentiles for large wild mammal crashes along US Hwy 90 in and around Bayou Teche NWR, Louisiana, USA.
4. COST-BENEFIT ANALYSES

4.1. Introduction

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in e.g. Hedlund et al., 2004; Knapp et al., 2004, Huijser et al., 2008). Examples include warning signs that alert drivers to potential animal crossings, wildlife warning reflectors or mirrors (e.g., Reeve & Anderson, 1993, Ujvári et al., 1998), wildlife fences (Clevenger et al., 2001), and animal detection systems (Huijser et al., 2006). However, the effectiveness and costs of these mitigation measures vary greatly. When the effectiveness is evaluated in relation to the costs for the mitigation measure, important insight is obtained regarding which mitigation measures may be preferred, at least from a monetary perspective.

For this report the researchers conducted cost-benefit analyses for four different types and combinations of mitigation measures. The types and combinations of mitigation measures evaluated for this report included:

- Fence, under pass (once every 2 km), jump-outs
- Fence, under- and overpass (underpass once every 2 km, overpass once every 24 km), jump-outs
- Fence, gap (once every 2 km), animal detection system in gap, jump-outs
- Animal detection system (not combined with a wildlife fence)

For details on the effectiveness and estimated costs of the mitigation measures per mile (1.609 km) per year and other methodological aspects of the cost-benefit analyses see Huijser et al. (2009). This publication also provides a rationale for the estimated costs associated with each deer-, elk-, and moose-vehicle collision. The cost for a collision is a combination of the average costs due to vehicle damage, human injury, human fatality, and lost wildlife value to hunters. Note that passive use values (e.g. the value of wildlife for tourism) were not included in these cost estimates. Should they be included, the benefits of implementing effective mitigation measures increase. The “benefit” of implementing effective mitigation measures is the collision costs that are avoided. The cost-benefit analyses were conducted over 75 years; consistent with the projected life span of concrete structures. The analyses were based on 2007 US $.

The cost for large mammal-vehicle collisions is expressed in dollars per year per mile (1.609 km). The cost estimates are based on a divided four-lane highway (two lanes in each direction) as the mitigation measures are more likely to be implemented with an overall road reconstruction that involves a wider and higher capacity highway then the implementation of mitigation measures as a stand-alone project along a two-lane road.

For this cost-benefit analysis, we used large wild mammal crash data provided by Louisiana DOTD. On average, large wild mammal crash data represent only 29.0% of large wild mammal carcasses that are removed from highways (Huijser, unpublished data). Thus, we conducted the cost-benefit analyses for the “reported crash data” as well as the “estimate for carcass removal
data”. The “estimate for carcass removal data” was calculate by multiplying the crash data by a factor 3.45 (1/0.29=3.45). Note that the correction factor is an estimate and that crash data with small sample sizes, especially many zero observations for individual 0.1 mi road segments, do not necessarily result in estimating the correct locations or concentrations for the “carcasses”.

The analyses include all large wild mammal species. In our case, we included white-tailed deer and black bear crashes. For the cost-benefit analyses, “deer” included black bear based on similarity in size and body weight. The costs per mile associated with large wild mammal-vehicle collisions were calculated for each 0.1 mile highway segment based on a running average for that 0.1 mile and half a mile up and half a mile down the highway (eleven 0.1 mile segments in total). This smoothened out potential spatial imprecision from data collectors who round off the location to the nearest 0.5 or 1.0 mile reference post.

Note that the cost-benefit model is primarily based on human safety parameters. If passive use values (e.g. wildlife viewing by tourists) were included in the cost-benefit analyses, then species with a high conservation value, such as black bear, could have a substantial influence on the outcome of the analyses, resulting in more and longer road sections that would meet or exceed the thresholds for the four different combinations of mitigation measures. Note that the cost-benefit analyses do not include costs associated with potential land acquisition.

Figures 16-18 show the costs associated with large wild mammal collisions based on crashes and estimated carcass counts for the three highway sections. There was not a single road section where the costs associated with large wild mammal-vehicle collisions reached or exceeded the thresholds of four different mitigation packages. Note that the costs associated with animal detection systems are estimated to be higher than for underpasses or overpasses. While the initial costs for an animal detection system may be lower than for concrete structures, concrete structures have a projected life span of 75 years while animal detection systems have a projected life span of only 10 years.

If mitigation measures are implemented, the justification cannot only be based on human safety costs parameters. The value of wildlife, including passive use values, needs to be part of the justification.
Figure 16: I-20 from Monroe (left side graph) to the Mississippi river (right side graph). The costs (jagged lines, in 2007 US$) associated with wildlife-vehicle crashes (dashed line) and estimated carcass counts (thin solid line) per year (annual average), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mile (160.9 m) long road unit concerned and adjacent units were summed to estimate the costs per kilometer.
Figure 17: US Hwy 65 from Jct with Hwy 605 (left side graph) to Tallulah (right side graph). The costs (jagged lines, in 2007 US$) associated with wildlife-vehicle crashes (dashed line) and estimated carcass counts (thin solid line) per year (annual average), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mile (160.9 m) long road unit concerned and adjacent units were summed to estimate the costs per kilometer.
Figure 18: US Hwy 90 from New Iberia (left side graph) to Morgan City (right side graph). The costs (jagged lines, in 2007 US$) associated with wildlife-vehicle crashes (dashed line) and estimated carcass counts (thin solid line) per year (annual average), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mile (160.9 m) long road unit concerned and adjacent units were summed to estimate the costs per kilometer.
5. STRATEGIES FOR SAFE CROSSING OPPORTUNITIES

5.1. Wildlife Crossings through Existing Bridges I-20

The Louisiana Department of Wildlife and Fisheries monitored nine bridges under I-20 for potential black bear crossings between 14 October 2014 – 2 February 2015 (Data provided by Maria Davidson, Louisiana Department of Wildlife and Fisheries). Black bears were not observed using the bridges that were constructed for rivers and streams (Table 2). During seasons with heavy rains and high water levels in the rivers, many of the bridges across rivers and streams have no dry space under the bridge, reducing the potential to be used by terrestrial mammals such as black bear. However, later in 2015, a few black bears were recorded under some of the bridges (Pers. com. Maria Davidson, Louisiana Department of Wildlife and Fisheries).

Table 2: The large wild animal species included for our analyses (Data provided by Maria Davidson, Louisiana Department of Wildlife and Fisheries).

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-tailed deer ( (Odocoileus virginianus) )</td>
<td>2185</td>
<td>67.69</td>
</tr>
<tr>
<td>North American raccoon ( (Procyon lotor) )</td>
<td>385</td>
<td>11.93</td>
</tr>
<tr>
<td>Human</td>
<td>267</td>
<td>8.27</td>
</tr>
<tr>
<td>Bobcat ( (Lynx rufus) )</td>
<td>213</td>
<td>6.60</td>
</tr>
<tr>
<td>Virginia opossum ( (Didelphis virginiana) )</td>
<td>113</td>
<td>3.50</td>
</tr>
<tr>
<td>Domestic cat ( (Felis catus) )</td>
<td>38</td>
<td>1.18</td>
</tr>
<tr>
<td>Nine-banded armadillo ( (Dasypus novemcinctus) )</td>
<td>13</td>
<td>0.40</td>
</tr>
<tr>
<td>Domestic dog ( (Canis lupus familiaris) )</td>
<td>10</td>
<td>0.31</td>
</tr>
<tr>
<td>Coyote ( (Canis latrans) )</td>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>Rabbit ( (Sylvilagus sp.) )</td>
<td>1</td>
<td>0.03</td>
</tr>
</tbody>
</table>

5.2. Potential Strategy for Locations Designated Safe Crossing Opportunities

We formulated three potential strategies for the implementation of highway mitigation measures for black bears:

1. Prioritize the road sections with the highest concentration of road mortalities.

The highest densities occurred along US Hwy 90 near Bayou Teche NWR, between Centerville (just west of Patterson) and Morgan City (Figure 11). This would, at least for now, address the road sections where black bears have been hit in the highest concentrations. It would reduce unnatural mortality and potentially increase the rate of population growth. But, unless the animals can expand their range without encountering
other lethal danger (e.g. collisions with vehicles at other locations, other types of human-bear conflicts), this strategy may not be the most effective to increase the long-term viability of the black bears in the region.

2. Prioritize the road sections where the black bear will have the highest probability of connecting to other existing populations or potential suitable habitat patches, and eventually effectively connect the black bear population in and around Tensas River NWR with the one in and around Bayou Teche NWR. This would result in a larger effective population in a network of habitat patches, safe corridors between the habitat patches, and ultimately reduced probability of regional extirpation. Note that the southern population in and around Bayou Teche NWR is smaller, and still effectively isolated from the populations further north, including those in and around Tensas River NWR (Davidson et al., 2015; Pers. com. Sean Murphy (Louisiana Department of Wildlife and Fisheries). The southern black bear population in and around Bayou Teche NWR has most to gain from measures aimed at restoring habitat connectivity to the populations further north.

Connectivity for black bears, including through safe crossing opportunities across highways, is likely most beneficial along the west side Mississippi, outside of the floodplain as the black bears have limited use of the floodplains and the existing bridges for highways in low and wet areas (Pers. com. Sean Murphy, Louisiana Department of Wildlife and Fisheries; see also paragraph 5.1). This means that the safe crossing opportunities (underpasses and potentially also overpasses) cannot necessarily be combined with existing crossing structures, especially not structures that are primarily designed for rivers and streams. Instead, we recommend adding new designated crossing structures that are specifically designed for black bear in dry areas, especially along highways in the Louisiana black bear Habitat Restoration Planning Area (HRPA) (Davidson et al., 2015). Providing safe crossing opportunities along highways in the southern area of the HRPA (i.e. I-10 between Lafayette and Baton Rouge), and US Hwy 90 between New Iberia and Morgan City) is critical (Figure 19). Currently, the vast majority of the black bears in and around Bayou Teche NWR are south of US Hwy 90 (Pers. com. Sean Murphy, Louisiana Department of Wildlife and Fisheries). To connect the black bear in and around Tensas River NWR to the ones north of I-20 and Arkansas, connectivity across I-20 is required (Figure 20) (Pers. com. Kelly Purkey, US Fish and Wildlife Service). The section of I-20 between Delhi and Tallulah also has a relatively high incidence of black bear road mortality which would be mitigated at the same time.
Figure 19: Yellow arrows indicate road sections (US Hwy 90 between New Iberia and Houma, and I-10 between Lafayette and Baron Rouge) where connectivity is needed most to connect the black bear population in and around Bayou Teche NWR to the populations further north (north of I-10).

Figure 20: Yellow arrows indicate road sections (I-20 between Delhi and Tallulah) where connectivity is needed most to connect the black bear population in and around Tensas River NWR to the populations further north in Arkansas (north of I-20).
3. Prioritize the road sections with the highest concentration of large wild animal crashes and assume that black bear will also benefit.

The highest densities of large mammal-vehicle collisions occurred along I-20 near Tensas River NWR, between Monroe and east of Delhi. This is not where black bear have been hit most frequently or where black bear would benefit most from increased connectivity between the areas on opposite sides of highways (compare figures 8-11 – Figures 12-15). Therefore, this strategy is not very effective for reducing black-bear collisions or improving connectivity across highways for black bear.

While the second strategy is likely the most effective for the long-term population viability of black bears, the reality is that mitigation measures such as crossing structures in combination with wildlife fences are rarely implemented as stand-alone projects. Especially underpasses and overpasses are typically combined with road (re)construction as it is substantially less expensive, and it also minimizes delays for traffic. Therefore, it is advisable to carefully evaluate if mitigation measures should be incorporated into any road (re)construction project. In the case of the Louisiana black bear, it is advisable to include mitigation measures for all road (re)construction projects in the range of the black bear or in the black bear Habitat Restoration Planning Area (HRPA) (Davidson et al., 2015).
6. FENCE AND CROSSING STRUCTURE CHARACTERISTICS

6.1. Mitigation Measures Considered

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in e.g. Hedlund et al., 2004; Knapp et al., 2004, Huijser et al., 2008). Examples include warning signs that alert drivers to potential animal crossings, wildlife warning reflectors or mirrors (e.g., Reeve and Anderson, 1993, Ujvári et al., 1998), wildlife fences (Clevenger et al., 2001), and animal detection systems (Huijser et al., 2006). Most of the most commonly applied measures (e.g. standard and enhanced wildlife warning signs) are ineffective at reducing direct road mortality and also do not address the barrier effect of highways (Huijser et al., 2015a). However, only wildlife fences in combination with wildlife crossing structures (underpasses and overpasses) and animal detection systems reduce collisions with large mammals substantially (>80% reduction in collisions) (see review in Huijser et al., 2009). However, animal detection systems have a wider range of effectiveness in collision reduction (33-97%) than wildlife fences in combination with wildlife crossing structures that are well designed over distances of at least three miles (Huijser et al., 2015a; Huijser et al., 2016a). Perhaps most important, many animal detection system projects fail and therefore they should still be considered experimental (Huijser et al., 2015a). In addition, animal detection systems do nothing to reduce the barrier effect of a highway; the animals still need to cross the same pavement that cars drive on. Furthermore, animal detection systems are only suited for relatively low traffic volume roads as sudden braking can lead to rear-end collisions (Huijser et al., 2015a). Animal detection systems are rarely implemented along roads with more than 10,000 vehicles per day (Huijser et al., 2015b). The traffic volume on most of the major highways crossing the habitat of the Louisiana black bear are much higher than that (Table 3). With high traffic volume (e.g. >10,000 AADT) and projected further increase in traffic volume, physical separation of wildlife and traffic is required. If the main purpose of a project is to reduce direct road mortality and to also provide safe crossing opportunities, wildlife fences in combination with safe crossing opportunities are the measures that have the highest probability of achieving the objectives. Therefore, we only recommend wildlife fences in combination with wildlife crossing structures for the Louisiana black bear.
Table 3: Average Annual Daily Traffic volume (AADT) for four major highways cutting through Louisiana black bear habitat (LADOTD, 2019).

<table>
<thead>
<tr>
<th>Highway</th>
<th>Mile Reference Point</th>
<th>Location</th>
<th>AADT</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-10</td>
<td>123.92</td>
<td>Just west of bridges across Atchafalaya River</td>
<td>55,778</td>
<td>2016</td>
</tr>
<tr>
<td>US Hwy 90</td>
<td>147.77</td>
<td>Between Jeanerette and Franklin</td>
<td>17,375</td>
<td>2017</td>
</tr>
<tr>
<td>I-20</td>
<td>169.8</td>
<td>Between Delhi and Tallulah</td>
<td>20,727</td>
<td>2015</td>
</tr>
<tr>
<td>US Hwy 65</td>
<td>43.87</td>
<td>Between Tallulah and Newellton</td>
<td>1,594</td>
<td>2015</td>
</tr>
</tbody>
</table>

We recommend a combination of fences designed for black bear, combined with designated crossing structures for black bear. The fences have two functions:
1. Keep the animals off the highway, reduce collisions and reduce unnatural mortality.
2. Guide the animals towards safe crossing opportunities.

The crossing structures also have two functions:
1. Provide a safe crossing opportunity for the animals to the other side of the highway.
2. If crossing structures are built in sufficient number, at the right locations, and if they are of the right type and dimensions, animals are less likely to breach the fence. In this context, crossing structures can also help reduce wildlife-vehicle collisions.

It is important that not only fences are built. Fences alone can reduce collisions and unnatural mortality, but they result in an absolute barrier. Crossing structures with no or limited fences can have high wildlife use, but they do not necessarily reduce collisions and unnatural mortality (Huijser et al., 2016a). Therefore, we recommend wildlife fences in combination with wildlife crossing structures.

6.2. **Recommended Characteristics Black Bear Fences**

Black bear can climb trees, and they can also climb wooden fences posts. Therefore, we recommend smooth metal posts rather than wooded posts (Huijser et al., 2015b) (Figure 21, 22). Furthermore, we recommend tall fences (e.g. 10 ft high) and an overhang or lip facing away from the road (Figure 21, 22). The fence material must be tough and able to resist teeth and claws, and the mesh size should be small enough so that black bear cannot put their feet in a mesh and climb a fence. Chain-link fence material seems to be the best choice for black bear (Huijser et al., 2015b). The fence material should be attached to the safe side of the fence; not to the road side (Huijser et al., 2015b). Because bears can dig, a dig barrier (or apron) (3 ft) attached to the fence, angled away from the road is also recommended (Huijser et al., 2015b)
(Figure 23). It is advisable to make fences for black bear also a barrier for the most frequently recorded large wild mammal in the area: white-tailed deer. In addition, especially near streams, rivers, and other water bodies, the fence should also be a barrier to north American river otter (*Lontra canadensis*) and American alligator (*Alligator mississippiensis*).
Figure 22: Wildlife fence for black bear (*Ursus americanus*), 3 m high (10 ft), chain-link, metal posts, US Hwy 64, near Roper, North Carolina, USA.

Figure 23: Wildlife fence, primarily for ungulates because of the large mesh size of the wire mesh fence, and a chain-link dig barrier, Trans-Canada Highway, Banff National Park, Alberta, Canada. The dig barrier is attached to the main fence, buried at an angle away from the road. The dig barrier keeps animals from digging under the fence.
Access roads and fence ends on the main highway should not be access points for black bear into the fenced road corridor. Wildlife guards (modified) cattle guards are a substantial barrier for large ungulates, but not for black bear (Allen et al., 2013). For black bear, electric mats or electric concrete are recommended (Gagnon et al., 2010) (Figure 24). Jump-outs or escape ramps allow animals to escape from the fenced road corridor (Figure 25). Jump-outs should be high enough so that animals do not readily jump into the fenced road corridor. At the same time, they should be low enough so that animals will readily jump down to the safe side of the fence. A height of around 1.5-1.6 m (5-5.5 ft) seems to function best for deer, but more research is required on effective designs for jump-outs (Huijser et al., 2015b). For black bear a metal face may be helpful as this makes it more difficult for them to climb the face of a jump-out (Figure 26).

Figure 24: Electric mat associated with an animal detection and driver warning system at a fence end, S.R. 260 east of Payson, Arizona, USA. The fence is a 2.4 m (8 ft) high electric fence (Electrobraid™/CrossTek™).
Figure 25: Wildlife fence and jump-out associated with an underpass, near Havre, Montana, USA.

Figure 26: Wildlife jump-out or escape ramp with a smooth metal face to reduce the likelihood that bears will climb the jump-out and end up in fenced right-of-way, Banff National Park, Alberta, Canada.
6.3. **Recommended Characteristics Safe Crossing Opportunities**

Clevenger and Huijser (2011) summarized the suitability of different types and dimensions of structures for different wildlife species. For black bear, the recommendations are summarized in Table 4).

Table 4: The types and dimensions of crossing structures recommended for black (based on Clevenger and Huijser (2011)). The width is from the animal's perspective when approaching the structure.

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Width (Minimum)</th>
<th>Width (Recommended)</th>
<th>Height (Minimum)</th>
<th>Height (Recommended)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape bridges (e.g. tunnels or very large overpasses)</td>
<td>70 m (230 ft)</td>
<td>&gt;330 ft (&gt;100 m)</td>
<td>n/a</td>
<td>n/a</td>
<td>Soil depth for small trees: 1.5–2.4 m (5–8 ft), add berms or fences to reduce visual and noise disturbance</td>
</tr>
<tr>
<td>Wildlife overpasses</td>
<td>40–50 m (130–165 ft)</td>
<td>(50–70 m (165–230 ft)</td>
<td>n/a</td>
<td>n/a</td>
<td>Soil depth for small trees: 1.5–2.4 m (5–8 ft), add berms or fences to reduce visual and noise disturbance</td>
</tr>
<tr>
<td>Long bridges (viaducts)*</td>
<td>30 m</td>
<td>&gt;100 m</td>
<td>5 m</td>
<td>&gt;7 m</td>
<td></td>
</tr>
<tr>
<td>Large mammal underpasses</td>
<td>7 m (20 ft)</td>
<td>&gt; 12 m (&gt;40 ft)</td>
<td>4 m (10 ft)</td>
<td>&gt;4.5 m (&gt;15 ft)</td>
<td></td>
</tr>
</tbody>
</table>

*Long bridges or viaducts are usually built because of rivers or topography and are at least several dozens of meters wide (from the animal’s perspective), partially based on Pers. com. Marcel Huijser.
Note that black bear also use smaller structures (e.g. box culverts about 6 ft high, 4 ft tall), but their use is generally lower than large mammal underpasses (Huijser et al., 2016b).

Based on the camera data summarized in section 5.1 and discussions with Louisiana black bear experts in the region (section 5.2) it is important that designated structures under highways are constructed in relatively dry areas. Solely relying on existing structures primarily built for other purposes is unlikely to result in substantial connectivity. However, it is advisable to tie the wildlife fences in to existing structures to maximize their potential as wildlife crossing structure, despite their limited use by black bear.

Note that overpasses may be difficult to realize because of land acquisition or easements for the approaches, and potentially unstable wet soils. Therefore, long bridges and large mammal underpasses are the most likely crossing structure types for the Louisiana black bear. Nonetheless, care must be taken that the structures have a bottom that is level with the surrounding area and that they are not flooded.

Figure 27: Elevated road for black bear (*Ursus americanus*), US Hwy 64, near Roper, North Carolina, USA.
Figure 28: Large mammal underpass, US Hwy 93, near St Ignatius, Flathead Indian Reservation, Montana, USA.
7. REFERENCES


