COST JUSTIFICATION AND AN EXAMPLE OF COST-BENEFIT ANALYSES OF MITIGATION MEASURES AIMED AT REDUCING COLLISIONS WITH CAPYBARA IN SÃO PAULO STATE, BRAZIL

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ABSTRACT

We analyzed capybara (*Hydrochoerus hydrochaeris*) carcass data for a highway in São Paulo State, Brazil. Capybara are frequently reported as road-kill and, because of their size and weight, they can cause substantial vehicle damage and are a serious threat to human safety. However, in addition to human safety, wildlife conservation concerns can also trigger the implementation of mitigation measures. For this paper we investigated a potential third argument for the implementation of mitigation measures: economics. We calculated vehicle repair costs associated with capybara-vehicle collisions based on interviews with personnel from car repair shops. In addition, we reviewed the effectiveness of wildlife fencing in combination with wildlife crossing structures in reducing collisions with large mammals. We then estimated the costs for four mitigation measures (fencing with and without three types of culverts). These data were used to conduct cost-benefit analyses over a 75-year period using a discount rate of 3 % to identify the threshold values (in 2012 R$) above which the four individual mitigation measures start generating benefits in excess of costs. Next we calculated the costs associated with capybara-vehicle collisions along a two lane highways in São Paulo State, Brazil. This calculation was spatially explicit and illustrated that the costs associated with capybara-vehicle collisions on specific locations along the highway exceed the threshold values for the four mitigation measures. We believe the cost-benefit model presented in this paper can be a valuable decision support tool to help select locations and implement mitigation measures that improve human safety, are likely to benefit nature conservation, and are economically justified even when based on very conservative cost-benefit analyses. We do stress though that the threshold values presented in this paper are based on a series of assumptions and estimates and that they should be taken as indicative values rather than exact values.

Keywords: economic, fence, investments, justification, road mortality, road ecology, underpass, wildlife–vehicle collisions.

INTRODUCTION

Wildlife-vehicle collisions affect human safety, property and wildlife. The total number of large mammal-vehicle collisions has been estimated at one to two million in the United States and at 45,000 in Canada annually (Conover et al. 1995, Tardif & Associates Inc. 2003, Huijser et al. 2007). These numbers have increased even further over the last decade (Tardif & Associates Inc. 2003, Huijser et al. 2008). In the United States, these collisions were estimated to cause 211 human fatalities, 29,000 human injuries and over one billion US dollars in property damage annually (Conover et al. 1995). In most cases the animals die immediately or shortly after the collision (Allen and McCullough 1976). In some cases it is not just the individual animals that suffer. Road mortality may also affect some species on the population level (e.g. van der Zee et al. 1992, Huijser and Bergers 2000), and some species may even be faced with a serious reduction in population survival probability as a result of road mortality, habitat fragmentation and other negative effects associated with roads and traffic (Proctor 2003, Huijser et al. 2008). In addition, some species also represent a monetary value that is lost once an individual animal dies (Romin and Bissonette 1996, Conover 1997).

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in Knapp et al. 2004, Huijser et al. 2008). Examples include warning signs that alert drivers of 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). However, the effectiveness and costs of these mitigation measures vary greatly (Huijser et al. 2009). 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. Examples of existing cost-benefit analyses for highway mitigation measures for wildlife are Reed et al. (1982) and Huijser et al. (2009).

In this paper we provide a justification for the monetary costs and benefits of a wildlife fencing in combination with three differently sized culverts aimed at reducing collisions with one of the most commonly reported road-killed large mammals in in São Paulo State, Brazil: capybara (*Hydrochoerus hydrochaeris*). Capybaras are the world's largest rodent and adults stand about 50 cm tall and can weigh around 54 kg (males) -62 kg (females) (Eisenberg & Redford 1999, Ferraz *et al.* 2005). These rodents of unusual size are considered food and habitat generalists, have high reproductive capacity, and combined with a decline of large predators, they can reach high population densities in anthropogenic landscapes, including the central region of São Paulo State (Verdade & Ferraz 2006, Garcias & Bager 2009). Because of the size and weight of capybara and their abundance, collisions with vehicles are a serious concern. Not only do they result in substantial damage to vehicles but they can also affect human safety (EM 2011, OGLOBO 2011, UOL Notícias 2011). Previous studies that reported on roadkill in central and southern Brazil also found capybara frequently hit by traffic, especially in the Atlantic ecoregion (e.g. Cáceres *et al.* 2010).

In addition we conducted cost-benefit analyses for mitigation measures aimed at reducing collisions with capybara. We hypothesized that, similar to ungulates in North America (e.g. Reed *et al.*1982, Huijser *et al.* 2009), the costs associated with capybara-vehicle collisions on certain road sections may be greater than the costs associated with implementing mitigation measures aimed at keeping capybara from accessing the highway and at providing safe crossing opportunities. This would then provide an important third argument to implement highway-wildlife mitigation measures in Brazil and specifically in São Paulo State; mitigation measures not only benefit human safety and nature conservation but they can also be a wise economic investment.

METHODS

Carcass Removal Data

We obtained carcass removal data from a 247 km long 2-lane highway in São Paulo State (ARTESP 2012). The carcass removal data were collected between 1 January 2010 and 31 October 2010. The highway is a toll road and the organization responsible for the operation and maintenance checks the entire length of the highway every 1.5 hours for potential problems (e.g. stranded motorists, debris (including road-killed animals) on road). The road maintenance crews recorded the date, species, number and location of the road-killed animals to the nearest 1.0km. The provider of the data did not allow us to display the name of the highway. We also set the start point for the highway at 0.0km regardless of the actual km markers located along the highway to avoid revealing the highway and location along the highway. While other species were also hit along the highway we only included observations of capybara for our analyses.

The carcasses were only available for 10 months (1 January 2010 through 31 October 2010). We estimated the number of road-killed capybara for November and December by analyzing the seasonal distribution of capybara roadkill along other highways in São Paulo State (Huijser et al. submitted). The capybara carcasses in November and December represented 21.65 % of the yearly total. Thus the correction factor applied to the data for the highway featured in this paper was 1/(1-0.2165)=1.28.

Mitigation Measures for Capybara

We evaluated four different mitigation measures or combinations of mitigation measures in our cost-benefit analyses for capybara:

- Chain-link fencing (1.5m high) with concrete posts. This type of fencing is considered a barrier to capybara. This fence looks similar to that in Figure 1, but without the concrete bottom/foundation. Instead the chain-link fence extends to the ground.
- Fencing (see above) with 1.70m diameter culverts (Fig. 2) and wildlife jump-outs (for photo see Huijser et al. 2009). Jump-outs are earthen ramps that allow animals that are trapped in between the fences in the road corridor to walk up to the top of the fence and jump down to safety. Well-designed jump-outs are low enough to allow animals to jump to safety, and high enough to discourage them from jumping up into the road corridor. While we do not know if capybara use jump-outs we did include these escape opportunities in the mitigation.
- Fencing (see above) with 2.00m diameter culverts and wildlife jump-outs.
- Fencing (see above) with 3.00x3.00m box culverts (Fig. 3) and wildlife jump-outs.

FIGURE 1. An example of the 1.5m high chain-link capybara fence evaluated for the cost-benefit analyses (Copyright © 2011, by Manetoni). Note that the fence in the photo shows a concrete bottom/foundation. For our cost-benefit analyses we did not include this concrete foundation; instead the chain-link fence extended to the ground.

FIGURE 2. An example of a 1.7m diameter culvert under a highway evaluated for the cost-benefit analyses (Copyright © 2012, by Fernanda D. Abra).

FIGURE 3. An example of a box culvert under a highway evaluated for the cost-benefit analyses (Copyright © 2012, by Fernanda D. Abra). Note that this particular culvert measures 2.00x2.00m and that we evaluated a culvert that is 3.00x3.00m.

The fencing is considered a substantial barrier to capybara and all three types and dimensions of culverts are considered suitable for capybara (Abra 2012). We estimated the fencing, with or without culverts, to reduce capybara-vehicle collisions by 86 % based on other studies for large mammals: Reed *et al.* (1982) 79 %; Ward (1982): 90 % Woods (1990): 94-97 %; Clevenger *et al.* (2001): 80 %; Dodd *et al.* (2007): 87 %).

Wildlife fencing alone increases the barrier effect of roads and traffic and causes further habitat fragmentation. To avoid this unintended consequence of fencing it is considered good practice to not increase the barrier effects of roads and traffic (e.g. through fencing) without also providing for safe crossing opportunities for wildlife (e.g. through wildlife underpasses and overpasses). It is also considered good practice to provide escape opportunities (e.g. wildlife jump-outs) for animals that do end up in the fenced road corridor. While we did include fencing as a stand-alone mitigation measure in our cost-benefit analyses we discourage the implementation of fencing without also providing for safe crossing opportunities for wildlife and a means to escape from the fenced road corridor. Connectivity across roads for wildlife is also in the interest of human safety as animals are more likely to break through a barrier (e.g. wildlife fencing) if safe crossing opportunities are not provided or if they are too few, too small, or too far apart.

Cost Estimates Capybara-Vehicle Collisions

We estimated the average vehicle repair costs as a result of a collision with capybara based on interviews with employees of car repair shops in the area around the city of São Paulo in June 2012. We only included vehicle repair costs in our estimates as we were unable to obtain data on the costs associated with the occasional human injuries and human fatalities, towing, accident attendance and investigation, and the cost of disposal of the animal carcass. Passive use costs were also not included in our cost-benefit analyses. Since passive use costs are very unlikely to be zero, the benefit-cost results reported in this paper should be considered conservative.

We asked the employees of ten car repair shops for their minimum and maximum cost estimates for vehicle repair as a result of a collision with capybara. The personnel based their estimates on their experiences with repairs on one of the most popular cars in Brazil: Volkswagen Gol. The average for the minimum was R$ 1,720 and the average for the maximum was R$ 4,050. We then calculated the average of the maximum and minimum estimates for each car repair shop to estimate the average costs for the repair; R$ 2,885.

For our cost-benefit analyses we assumed that all collisions involving capybara resulted in vehicle damage and vehicle repair costs. However, collisions that result in no or minor damage may not cause the owner of the vehicle to have the damages repaired in a shop. This could mean that the costs for an average capybara-vehicle collision may be lower than the estimates derived from the interviews. On the other hand it is unlikely that all carcasses are observed and reported, which results in an underestimate of the costs associated with capybara-vehicle collisions along the various road segments. More importantly, some vehicles are smaller than the brand and model we based our estimates on and are therefore more likely to sustain more damage. However, larger vehicles, especially large trucks, may not sustain much damage at all. If and when better data are available on the costs associated with vehicle repairs and other costs associated with capybara-vehicle collisions it would allow for more precise cost-benefit analyses.

Cost Estimates Mitigation Measures for Capybara

We estimated the cost of the four different types and combinations of mitigation measures based on a review of the literature and interviews with researchers and transportation agency personnel (see Huijser *et al.* 2009; City of São Paulo 2012). The costs were calculated for a 2-lane motorway (1 lane in each direction, no median) and standardized as costs per kilometer road length. Unless indicated otherwise, all cost estimates were expressed as R$ (Brazilian Real (BRL)). We obtained costs for fencing and three different types of underpasses in 2012 in 2012 R$. Other costs (operation, maintenance, removal, jump-outs) were based on Huijser *et al.* (2009). However, the US$ values were now made to be R$ values which essentially cut the cost estimates about in half (1 US$ was 2.03 R$ on 25 July 2012). We think this was justified and still conservative as we compared the costs of the culverts evaluated in these cost-benefit analyses to similar sized culverts in Montana and found the costs for the culverts in Brazil to be only about 27 % of the costs for the culverts in Montana. Therefore we argue that other construction and also operation, maintenance and removal costs are likely overestimated rather than underestimated when replacing the US$ with R$ and keeping the numbers the same, effectively putting these costs at about 50 % of the costs in North America.

The costs for the capybara fence was estimated at R$ 70 per meter (R$ 140,000 per km road length with fence on both sides of the road) (Manetoni 2011; R$ 65-75 per meter depending on the road length that needs to be fenced). The projected life span of this wildlife fence was set at 25 years. Fences require maintenance, for example as a result of fallen trees, vehicles that have run off the road and into the fence, and animals that may have succeeded digging under the fence (Clevenger *et al.* 2002). Therefore maintenance costs were set at R$ 500 per km per year and fence removal costs were set at R$ 10,000 per km road length.

For our cost benefit analyses we set the number of safe crossing opportunities at one per 2km (0.5 crossing opportunity per km). This number is based on the actual number of crossing structures found at three long road sections (two lanes in each travel direction) that have wildlife fencing and crossing structures for large animals: 24 crossing structures over 64km (0.38 structures per km) (Foster & Humphrey 1995); 24 crossing structures over 45km (0.53 structures per km) (Clevenger *et al.* 2002); and (17 crossing structures over 31km (0.56 structures per km) (Dodd *et al.* 2007). While it may require a different density of crossings to maintain viable wildlife populations in a landscape bisected by roads, a density of 0.5 crossing opportunities per km is based on actual practice which make our cost-benefit analyses most realistic.

For the purposes of our cost-benefit analyses for wildlife fencing in combination with safe crossing opportunities we distinguished between three types of culverts (Table 1). The motorway we conducted the cost-benefit analyses for have one in each direction and no median in between. We calculated the length of the culverts to be 17.5m; two lanes are typically 15-17m wide.

TABLE 1. The costs for the three types of culvert used in our cost-benefit analyses (based on City of São Paulo 2012).

Culvert type	Cost (R$/m)	Costs for one structure along 2-lane motorway (17.5 m culvert length) (R$)
1.70 m diameter culvert	R$ 805.92	R$ 14,103.60
2.00 m diameter culvert	R$ 1,162.57	R$ 20,344.98
3.00 m x 3.00 m box culvert	R$ 1,662.47	R$ 29,093.23

Maintenance and operation costs were estimated at RS $2,000 per structure per year (R$1,000 per km per year). The projected life span of an underpass was set at 75 years. Structure removal costs were estimated at R$ 30,000 per structure (R$ 15,000) per km). The length of the fence was not reduced because of the gap as a result of the crossing structure, as the fence is angled towards the road and ties in with the crossing structure. For our cost-benefit analyses we used jump-outs or escape ramps as escape opportunities for large animals. The reported costs for one jump-out are US$ 11,000 (US$ 13,200 in 2007 US$) (Bissonette & Hammer 2000) and US$ 6,250 (2006) (US$ 6,425 in 2007 US$) (Personal communication Pat Basting, Montana Department of Transportation). We set the costs for a jump-out at R$ 9,813 with a projected life span of 75 years. The number of escape ramps between crossing structures was set at 7 per roadside per 2km (2 immediately next to a crossing structure (50m on either side from the center of the structure), and an additional five escape ramps with 317m intervals (7 per km; R$ 68,691 per km). The escape ramps on either side of a crossing structure are required because of the continuous nature of the wildlife fencing and the assumption that animals will want to cross the road most often at the location of the crossing structures, as that should be one of the most important criteria for the placement of these crossing structures.

Cost-Benefit Analyses for Capybara

We based our cost-benefit analyses on the model we presented in an earlier paper (Huijser *et al.* 2009) and a submitted manuscript (Huijser et al. submitted). We refer to these papers for full details on our cost-benefit analyses, including formula. Note that the results of our economic analyses apply to Brazil (specifically São Paulo State), but not necessarily to other countries or regions, because we used species characteristics and economic data from São Paulo State only. Furthermore, we realize that the results of the analyses are directly dependent on the parameters included in the analyses and the assumptions and estimates required to conduct the analyses. Nonetheless, the results of the cost–benefit analyses allow for much needed direction for transportation agencies and natural resource management agencies in the implementation and further research and development of mitigation measures aimed at reducing collisions with large mammals and providing safe crossing opportunities for wildlife.

Illustration Output Cost-Benefit Model

We used the carcass removal data from the highway to illustrate the outcome of the cost-benefit model and to investigate if there are road sections along the highway that reach or exceed the thresholds for the four different mitigation measures. To investigate the presence of potential hotspots for capybara-vehicle collisions and associated costs we conducted a spatially explicit cost-benefit analysis at a resolution of 1.0km. We only conducted the analyses for a discount rate of 3 % and assuming average vehicle repair costs.

RESULTS

The costs, calculated per km per year, was not that much higher for slightly larger culverts (3 x 3 m) compared to smaller culvert (e.g. 1.7 m diameter) (Table 2).

TABLE 2. The costs (in R$ per km/year) for the wildlife fence, jump-outs, and the three types of culvert used in our cost-benefit analyses.

Mitigation measures	Threshold (R$)
Fence and jump-outs	R$ 8,831
Fence, jump-outs, and 1.70 m diameter culvert	R$ 12,470
Fence, jump-outs, and 2.00 m diameter culvert	R$ 12,575
Fence, jump-outs, and 3.00 m x 3.00 m box culvert	R$ 12,722

The costs associated with capybara-vehicle collisions display a very spiky spatial pattern (Fig. 4). This indicates that there are short road segments with a high concentration of capybara-vehicle collisions rather than a more diffuse distribution of these collisions. This also suggests that relatively short sections of fence can keep most of the capybara from getting on the road surface and being exposed to traffic.

The costs associated with capybara-vehicle collisions did reach and exceed the thresholds for the different mitigation measures in some road sections (Fig. 4). The benefits of fencing as a stand-alone mitigation measure exceeded the costs on 7.3 % of the 247 kilometer long highway. Similarly, this percentage was 4.5 % for fencing in combination with any of the three culverts. However, note that the costs are at each 1.0km and that the thresholds need to be exceeded for two consecutive kilometers to have the benefits of a mitigation measure that includes a safe crossing opportunity truly exceed the costs as our cost-benefit analyses include one culvert every 2 kilometers. On the other hand, if the costs associated with capybara-vehicle collisions are higher than the threshold, then these costs can carry over to neighboring road segments that may not have reached the threshold.

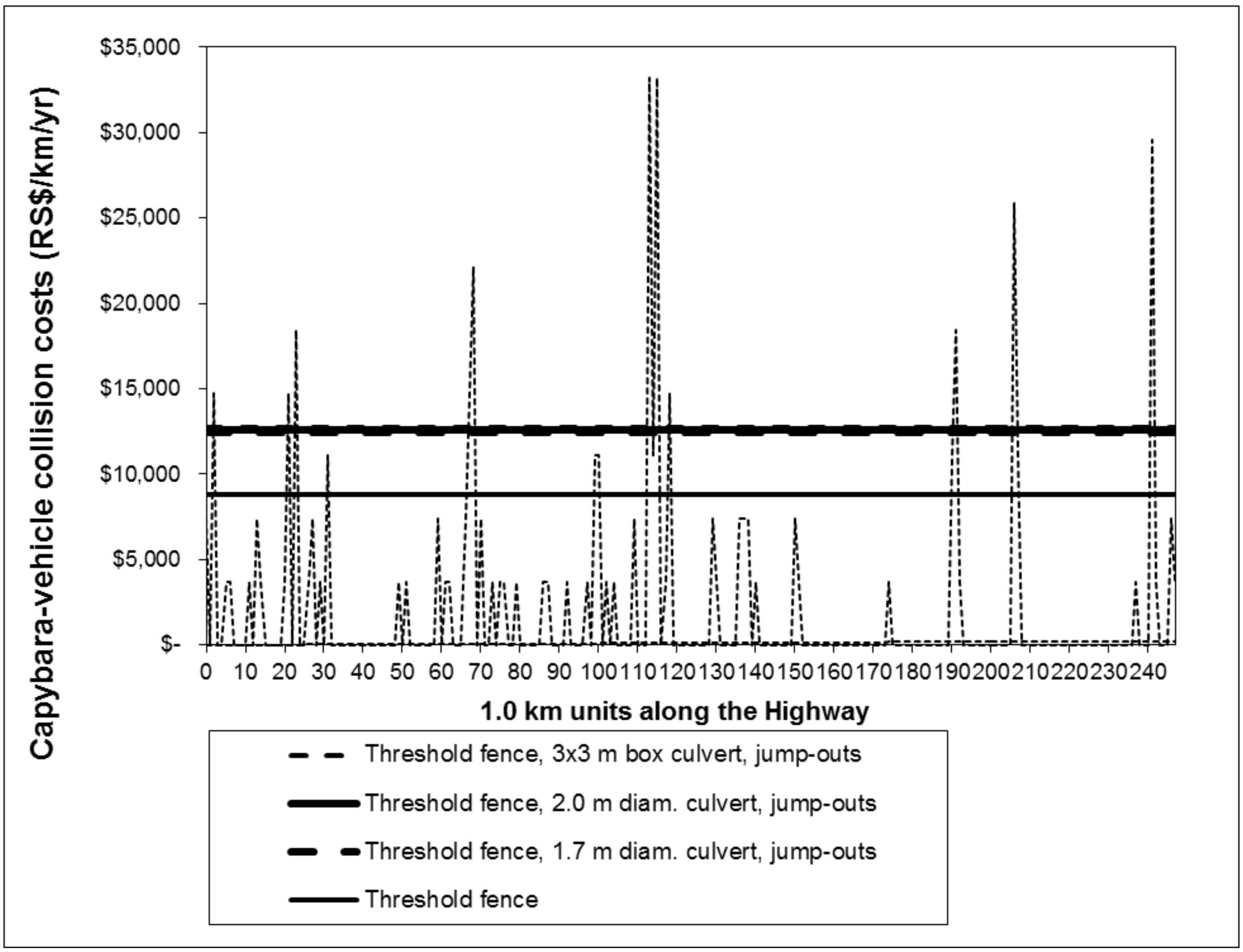

FIGURE 4. The costs (in 2012 R$) associated with capybara-vehicle collisions along the highway (based on data for 2010 only), and the threshold values (at 3% discount rate and average vehicle repair costs) that need to be met in order to have the benefits of the four individual mitigation measures exceed the costs over a 75 year long time period.

DISCUSSION

The highway is located in the vicinity of two large rivers and the habitat alongside the highway is likely quite suitable for capybara. We do not know how consistent road maintenance crews really are in recording road-kill and what percentage of the road-killed capybara end up in the databases. Therefore the roadkill data should be considered minimum numbers which means that the input into our cost-benefit models is conservative.

The cost-benefit analyses resulted in threshold values for individual mitigation measures (i.e. fencing and fencing combined with different sized culverts). The threshold values were expressed in 2012 R$ per kilometer per year. If he costs associated with capybara-vehicle collisions along certain road sections meet or exceed these threshold values, then implementing these mitigation measures is economically attractive; the benefits through reducing collisions with capybara through implementing mitigation measures exceed the costs associated with the mitigation measures.

We were unable to obtain data on the costs associated with the occasional human injuries and human fatalities, towing, accident attendance and investigation, the cost of disposal of the animal carcass, and passive use costs. This means that our analyses are relatively conservative; the real costs associated with capybara-vehicle collisions are likely to be much higher than our estimates which are based on vehicle repair costs only. For example, the vehicle repair costs associated with ungulate-vehicle collisions in North America were only a fraction of the total costs: 39.6 % for deer (*Odocoileus* spp.), 26 % for elk (*Cervus canadensis*), and 18.2 % for moose (*Alces alces*) (Huijser *et al.* 2009). Because the weight of capybara overlaps with that of white-tailed deer (*Odocoileus virginianus*) in North America (males 68-141 kg, average 89 kg; females 41-96 kg, average 62 kg) we can expect a somewhat similar risk for human injuries (5 % of all collisions with white-tailed deer) and fatalities (0.03 % of all collisions with white-tailed deer) (Whitaker 1997, Huijser *et al.* 2009, Foresman 2012). Evidence that capybara-vehicle collisions pose a serious threat to human safety is illustrated by various newspaper articles (e.g. EM 2011, OGLOBO 2011, UOL Notícias 2011). In North America the costs associated with human injuries and human fatalities were 56.0 % of the total costs for an average white-tailed deer-vehicle collision. This suggests that a more complete cost estimate for an average capybara-vehicle collision may be about twice as high if we not only include vehicle repair costs but also the costs associated with the occasional human injury and fatality.

Based on a spatially explicit cost-benefit analysis for the highway we investigated there were several road segments where the costs associated with capybara-vehicle collisions reached and exceeded the threshold values for all four mitigation measures. The costs associated with capybara-vehicle collisions appear to spike in very short road segments, allowing for efficient location of wildlife fencing and culverts. Closer investigation of satellite imagery (Google Earth) revealed that 16 out of the 17 one-kilometer road segments that exceeded at least one of the thresholds for the four mitigation measures were associated with stream crossings or water in the immediate vicinity of the highway. This suggests that while capybara are considered habitat generalists that mitigation measures for capybara-vehicle collisions are best implemented at stream crossings or areas where water or streams are in the immediate vicinity of a road.

Stream crossings require crossing structures because of hydrology alone. Since capybara tend to cross the road at or near stream crossings it seems efficient to implement larger structures wherever streams cross a road. These structures should preferably include dry banks for terrestrial species (e.g. Abra 2012, Clevenger & Huijser 2011). Since the majority of the costs for such a structure are related to hydrology rather than passing capybara, the thresholds for implementing a culvert that is suitable for capybara may be much lower than indicated in our cost-benefit analyses. Alternatively, existing culverts may be modified through providing walkways, either fixed or floating (see Foresman 2004, Kruidering et al. 2005, Clevenger & Huijser 2011). Note that the suitability of types of selves or planks for capybara may need to be investigated before implementing them at a large scale. Because of the close association of capybara-vehicle collision locations and stream crossing, the costs for mitigating capybara-vehicle collisions may be mostly with fencing rather than safe crossing opportunities. This analysis illustrates that a one-size fits all approach to use of this benefit-cost tool might miss some opportunities to implement cost-effective collision mitigation. For the case at hand, using the findings as a planning tool can help locate efficient locations for capybara mitigation on this set of highways in São Paulo State. Because the "hot spots" for capybara crossings and collisions are at stream crossings, culvert-related costs for capybara can be minimal and a larger set of collision hot-spots may meet the benefit-cost threshold test. In fact, fencing alone (which is the least expensive mitigation alternative) is likely the only measure specifically related to capybara and most of the costs associated with culverts at stream crossings should not really be attributed to mitigation for capybara.

Cost estimates for the mitigation measures were mostly based on current data from the region. Some cost estimates were based on data from North America, but as explained in the methods these estimates are likely to be overestimating rather than underestimating the costs associated with the implementation of the mitigation measures along highways in Brazil, specifically in São Paulo State. This means that the threshold values we calculated may be too high rather than too low and that the implementation of mitigation measures may be justified with lower numbers of capybara-vehicle collisions than we project in this paper. Interestingly, the threshold values for the three mitigation measures that included differently sized culverts were very similar. Apparently it does not matter very much if a slightly larger culvert is put in if you evaluate the costs over a 75 year long period. Of course the costs associated with collisions with capybara and the mitigation measures are a current estimate and may be subject to change when additional studies are conducted or when more and better data become available. The same is true for the costs (e.g. price of fuel, concrete, and steel) and estimates on the effectiveness of the individual mitigation measures, particularly with regard to reducing collisions with capybara.

CONCLUSION

While mitigation measures are mostly implemented because of concerns for human safety and nature conservation, this paper shows that economics can also justify mitigation measures aimed at reducing wildlife-vehicle collisions and providing safe crossing opportunities. We believe that the cost–benefit model that was applied to the data in this paper can be a valuable decision-support tool for transportation agencies and natural resource management agencies when deciding on the implementation of mitigation measures to reduce wildlife–vehicle collisions. In this case we acquired specific data on the costs associated with capybara-vehicle collisions and mitigation measures targeted at reducing these collisions and providing safe crossing opportunities for capybara. The results suggest that there are road sections in Brazil, and São Paulo State in specific, where the benefits of mitigation measures exceed the costs and where the mitigation measures would help society save money. This is in addition to improving road safety for humans through a reduction in collisions with capybara. Mitigation measures that include safe crossing opportunities for wildlife may not only substantially reduce road mortality, but also allow for wildlife movements across the road. This connectivity is essential to the survival probability of the fragmented populations for some species in some regions. The results of our cost-benefit analyses are quite conservative for various reasons, most notably because the cost estimates for the average capybara-vehicle collision only included the cost of vehicle repair. An important direction for future research would be to develop estimates for human injury and fatality costs, as well as passive use values, including for other, perhaps less common, species that may suffer from direct road mortality or habitat fragmentations as a result of roads and vehicles.

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Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present).

Fernanda D. Abra graduated in Biological Sciences (2009) and also has a MSc in Ecology from the University of São Paulo (2012). Her thesis focused on Road Ecology and was titled "Monitoring and evaluation of fauna underpasses along Highway SP-225, near Brotas, São Paulo State, Brazil. In 2011 Fernanda received two international grants from the Neotropical Grassland Conservancy and Rufford Small Grants. She is currently working on the environmental licensing of highways and railways and with the planning of wildlife crossings in the State of São Paulo.

John Duffield is a natural resource economist at the University of Montana. His background includes a PhD in economics from Yale (1974) and a BA (economics and math) from Northwestern (1968). John has contributed to the development and application of tools for the economic valuation of nonmarket resources such as fish, wildlife, recreation, and other ecosystem services. This work has helped inform public policy decisions that require weighing production of marketed goods against potentially foregone environmental services. Applications include critical habitat analysis for bull trout, valuation of wild salmon ecosystems in Bristol Bay, Alaska, proposed hydropower development on the American, Klamath, and Kootenai Rivers, wolf recovery in Yellowstone, and instream flow valuation. John was a member of the National Academy of Sciences panel on bear and wolf management in Alaska, and has participated in a number of significant natural resource damage cases, including ARCO v. Montana. John was the lead economist for the Alaska Native class in the *Exxon Valdez* oil spill case. A current project is evaluation of the impacts of Glen Canyon Dam on ecosystem services in the Grand Canyon of the Colorado. A long-term interest is in valuing cultural and natural resources in the tribal context.

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