Action: Creating wildlife corridors to enhance animal dispersal

Key Messages

- **10 studies** investigating the impact of human-constructed habitat corridors on wildlife are summarized: **5 include *underpasses*, 3 include *overpasses*,** and **3 include *planted stands and reforested segments***
- Each study focuses primarily on **1-3 target species**, including large-medium sized mammals (7), small mammals (3), and birds (1)
- **4 studies** included before and after construction comparisons
- Studies span the globe, with **3 in Canada, 2 in North America, 2 in Europe, 2 in South America, and 1 in Australia**
- **9 studies clearly found some improvement** in habitat connectivity and/or positive influence on movement patterns for target species

Background Information

Wildlife corridors have long been proposed as useful human interventions to combat habitat fragmentation and restore population ranges and movement patterns (Schultz 1998, Schultz and Crone 2005; Tewksbury et al., 2002)**.** Habitat fragmentation is detrimental for a number of reasons, including contribution to local and global species extinctions through loss of genetic diversity (Cushman et. al., 2006; Ferraz et. al., 2003). Restoration of functional connectivity between isolated habitat patches through the creation of corridors seeks to restore population gene flow, thereby encouraging species survival and persistence (Beier and Noss, 1998; Haddad et al., 2003; Soule and Gilpin, 1991; Wright, 1951).

Several different types of wildlife corridors have been proposed and established, often depending on the target species and specific challenge being faced (Beier and Noss 1998, Haddad et al. 2003). This action focuses on three main types of human-constructed corridors: underpasses, overpasses, and planted reforested passages. Underpasses and overpasses target issues of increasing infrastructure density, which fragment habitat through bisection of home ranges and contribute to species loss through animal collisions (Bennett 1990; Mader 1984). Planted restoration passages also aim to reconnect critical habitat, allowing renewal of population movement and enhanced animal dispersal (Beier and Noss 1998).

Despite widespread regard of corridors as a key tool in conservation biology, lack of data on their effectiveness has been a major source of criticism (e.g. Simberloff et al., 1992). Pre- and post-monitoring of the effectiveness of habitat corridors, as well as comparison to movement within and outside the corridor, are critical to properly characterize their success in maintaining habitat connectivity and population gene flow (Beier and Noss, 1998). Yet, such assessments are often neglected in the literature (Beier and Noss, 1998; Rosenberg et al., 1997). Monitoring techniques may focus on the abundance and usage patterns of one or more species depending on the corridor's goals. Common tracking methods include digital camera traps, infrared (IR) technology, track pads, snow tracking, live animal traps, genetic analysis, and computer modelling and simulations (Clevenger and Sawaya, 2010; Kusak, 2009). The advantages and disadvantages of these monitoring methods vary widely due to differences in quality and nature of information obtained, and comparison of their relative usefulness in evaluating corridor success is rare (Gužvica et al., 2014).

This action is devoted to comprehensively assessing the effectiveness of corridors at enhancing animal dispersal based on a variety of monitoring techniques. The results from the following 10 case studies serve as evidence for conclusions and future recommendations.

Supporting Evidence from Individual Studies

1. **Drainage culverts as habitat linkages and factors affecting passage by mammals**
   The effectiveness of culverts as wildlife corridors was investigated in this study. Specifically, 36 drainage culverts fully crossing the Trans-Canada Highway (TCH) and Highway 1A along Banff National Park (BNP) Alberta, Canada of various lengths, openness, and adjacent habitat were assessed. Usage patterns were evaluated in the winter months of 1999-2000 through weekly track pad monitoring within the corridor and footprint analysis in transects near the culverts. This data was used to compare observed vs. expected crossings, yielding a unique index for each species. Although at least 9 different species were detected, only 5 medium-sized mammals were included in analysis: coyote (*Canis latrans*), American marten (*Martes americana*), weasels (*Mustela erminea* and *M. frenata*), snowshoe hare (*Lepus americanus*) and red squirrel (*Tamiasciurus hudsonicus*). Results showed that different culvert attributes influenced usage index for each species. For instance, noise level negatively influenced snowshoe hare use, traffic volume negatively influenced coyote use, and culvert height positively influenced weasel use. Overall, traffic volume was the broadest significant factor, with all species but coyotes using the culverts more frequently with increased traffic, while adjacent habitat type showed little significance for most species. Based on these mostly species-specific patterns, the creation of multiple different culverts of varying shape, size, and environmental conditions is recommended.
2. **Wildlife use of existing culverts and bridges in North Central Pennsylvania**
   An assessment of the effectiveness of 45 existing drainage box culverts, arch culverts, and bridges as wildlife corridors of varying shape, size, substrate, and adjacent habitat was carried out in North Central Pennsylvania. The study was mostly targeted at movement and usage patterns of white-tailed deer (*Odocoileus virginianus*), as they are frequent victims and perpetrators of vehicle accidents in this region. The study consisted of two phases: 1) monitor of wildlife use of 9 culverts in Fall 2000 and 2) specific focus on white-tailed deer use of 20 identified culverts with large openness indices (i.e., overall size) and shorter lengths in Fall 2002 and Spring 2003. Monitoring involved identification of signs of wildlife and implementation of infrared remote cameras. In both phases, raccoons were the most abundant species detected, and all but one culvert had some sign of wildlife use. White-tailed deer were significantly more abundant in the second phase, as they were found in 9 of the 20 culverts compared to only 1 of 10 in the first

phase. Substrate type did not seem to influence deer usage of culverts, but insufficient surrounding habitat, consistent deep water levels, and entrance obstacles did limit deer ability to move through culverts. This study argues that for large mammals like white-tailed deer, these factors in combination with the openness index and length must be taken into special consideration when constructing culverts.

3. **Florida Key deer *Odocoileus virginianus clavium* underpass use and movements along a highway corridor**
   The usefulness of two wildlife underpasses and four deer guard barriers built in 2002 along a 5.6km segment of US Highway 1 in the Florida Keys was the target of this assessment. A different species of deer, the Florida Key deer (*Odocoileus virginianus clavium*), was the main focus of monitoring efforts, as the explicit purpose of the interventions was to minimize deer mortality from vehicle collisions and maintain deer movement through the Big Pine Key (BPK) corridor on the north-south axis. Researchers assessed the impacts of the improvements by radio-collaring 76 individuals and comparing their annual and core ranges pre (1998-2000) and post-establishment (2003-2004). Additional data was collected on deer-vehicle collisions before and after wildlife underpass construction, as well as underpass and natural corridor use through infrared-triggered cameras. Results showed that corridors were effective in maintaining deer movement, as annual and core ranges were similar for deer populations pre- and post-project. Deer-vehicle collisions also decreased by 94% with the construction of the underpasses, presumably decreasing overall deer mortality. Comparison of camera exposures revealed that deer generally needed a 6-month acclimation period before consistently using the underpasses. Despite lack of generalizability to other species and populations, this study reveals the effectiveness of targeted underpass construction in maintaining long-term habitat connectivity for a large mammal susceptible to anthropogenic road collisions.
4. **Cougar Puma concolor use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta**
   This study investigated cougar (*Puma concolor*) use of 20 wildlife underpasses (7 open-span bridge 3 creek bridge, 6 metal culvert, 4 concrete box culvert) and 2 overpasses constructed in November 1997 across the Trans-Canada highway in Bow River Valley of Banff National Park (BNP). The TCH is a major motorway connecting two large Canadian cities that bisects critical subalpine and valley bottom cougar habitat and deer foraging grounds. Effectiveness of the constructed corridors in maintaining courage movement year-round was assessed via track pads on all corridors and infrared cameras on overpasses between 1996-2000. A seasonal pattern in usage was detected, with cougars using corridors more than expected during winter months and less during summer. Cougar movement through the corridors was significantly correlated with the presence of two species of deer, indicating their usefulness in supporting uninterrupted prey-tracking. Overall, open-span bridge underpasses experienced the highest amount of cougar traffic, and all other types of underpasses and overpasses were inefficient in maintaining cougar movement. Interestingly, human traffic did not impact likelihood of cougar use, but quality of habitat surrounding the corridor played a large role. These

results support construction of underpasses (specifically, large open-span bridges) for a top predator in critical areas.

5. **The use of a motorway wildlife overpass by large mammals**
   Mammal corridor usage patterns were characterized for the Terlet wildlife overpass crossing the A50 Motorway in the Netherlands. The 50m wide corridor was built in 1989 to connect forest and heathland red deer (*Cervus elaphus*) habitat. Effectiveness was evaluated by comparing usage by large and small mammals through track pads and trapping shortly after construction in 1989 to ~5 years later, in 1994-95. In 1989, the corridor was mainly traversed by wild boar (*Sus scrofa*), whereas in 1994-95 red deer were most often detected as a result of a 3x increase in use. A seasonal change in usage pattern was also detected for both sampling periods, where wild boar and red deer used the corridor less frequently from late winter to early summer. Total number of passages and higher species composition was also found at the later sampling points, including larger species such as fallow deer (*Dama dama*) and Highland cattle (*Bos taurus*). This study highlights the importance of a habituation period for maintained seasonal corridor usage by target species.
6. **Comparative analysis of three different methods for monitoring the use of green bridges by wildlife**
   This study focused on the comparative effectiveness of different sampling methods for evaluating wildlife corridor construction projects. Specifically, the usefulness of digital camera traps, infrared (IR) detectors, and track pads over the course of three years (2009-2011) was investigated on 4 green bridges crossing the major north-south A1 Motorway in Croatia. Track pads were centrally located on the bridges and spanned their width; 4 IR transmitter and receiver sets were fitted above the ground on each bridge; and 4 continuously operated digital cameras were placed at the ends of all bridges. Each green bridge reported different counts of total passages and varied species composition. High abundance of roe deer (*Capreolus capreolus*) was found on green bridges located in the continental part of the highway, whereas small canids were found in large numbers along the entire stretch of the motorway, including on a green bridge in the Mediterraean region. Number of sightings at each bridge differed among all three monitoring methods, but IR consistently reported the highest number of events (most likely containing many false positives) and track pads consistently reported the lowest, severely underestimating small canid presence. Camera trap data was the most accurate at identifying species, but may underestimate the number of animals moving in large groups such as roe deer. Overall, a combination of monitoring techniques is needed to evaluate usage and movement patterns in species of various body and group sizes.
7. **Response of wolves to corridor restoration and human use management**
   Impact of a restored wildlife corridor on wolf (*Canis lupus*) movement was investigated in this study. Modified fencing on a golf course in Athabasca Valley of Jasper National Park (JNP) in Alberta Canada in November 2001 allowed wolves access to a previously barricaded section of forest. Change in usage patterns by wolfpacks was quantified by comparing winter snow tracking transects within and outside the corridor before (1 year)

and after restoration (2 years). Human use of forested trails in the corridor was measured as a potential confounding factor via infrared (IR) technology and local staff estimates. Factors such as elevation, slope, and prey abundance were also included in the analysis to capture the full picture on wolf movement in this region. Results showed that wolves used the corridor a higher proportion of the time after restoration (51-81% of detected passages vs. 1%), as anticipated. However, compared to mountainous areas, wolves neither preferably avoided nor selected the wildlife corridor, but did in general prefer areas with low human activity. Despite high concentrations of elk and deer species in the corridor, foraging rarely occurred in the area, revealing that wolves primarily used the corridor as a movement route. Post-restoration increase in wolf use of areas with low elevation, shallow slopes, and high prey abundance suggests that corridor creation allowed enhanced access to high quality habitat. Restoration of this corridor was overall successful in supplementing wolf habitat and improving connectivity, especially combined with decreased human activity in the area.

8. **Planted trees as corridors for primates at El Zota Biological Field Station, Costa Rica**
   The efficacy of planted stands as movement corridors is the focus of this study. Use of large-scale reforested areas (~270 ha) located in the El Zota Biological Field Station in northeastern Costa Rica by three species of primate (mantled howling monkey (*Alouatta palliata*), blackhanded spider monkey (*Ateles geoffroyi)*, and white-faced capuchin (*Cebus capucinus*)) was investigated. These stands were erected 8-10 years prior to the present study, primarily as part of a sustainable tree harvesting project, but preliminary observation suggests they could be used as travel corridors for animals between 700 ha of intact natural humid and swamp forest habitat. Focal group follows and scan sampling of group members allowed tracking of movement and activity patterns of these species among natural and planted areas, yielding a total of 50 hours of data. Analysis of the data showed that reforested areas were mostly used as travel and resting sites. Foraging rarely occurred in areas of reforested habitat (two of the species spent 0% of their time feeding in the corridors), most likely due to differences in tree species composition and quality between forested and reforested patches. While such planted corridors may not provide much opportunity for primate settlement, their use as a travel corridor is undisputed. Erection of fast-growing nonnative species is therefore recommended for habitat connectivity purposes.
9. **Monitoring movement into and through a newly planted rainforest corridor using genetic analysis of natal origin**
   Genetic analysis was employed in this study to assess small native mammal dispersal patterns through a planted corridor. Specifically, Cape York Rat (*Rattus leucopus*) and Bush Rat (*Rattus fuscipes*) use of Donaghy's Corridor in the Wet Tropics World Heritage Area of northern Queensland, Australia was investigated. The corridor consists of four planted stands established between 1995-1998 to connect the Lake Barrine section of Crater Lakes National Park (498 ha) with 80,000 ha of tropical rainforest in the Gadgarra Forest section of Wooroonooran National Park, two areas that were previously contiguous but have been fragmented since the 1900s. The effectiveness of the habitat

corridor was assessed by trapping quarterly from 1997-2000 in Lake Barrine and Gadgarra Forest, as well as each section of the linkage. Starting in 1998, ear clippings were also collected for species identification and natal origin genetic analysis. Genetic and trapping results showed that there was little population connection prior to the establishment of the habitat corridor, and only short-distance movement between adjacent areas was detected during this time. Long-distance movement was only discovered with genetic data (16 total instances), consisted primarily of Bush rats, and mostly occurred directly following erection of the corridor. Interestingly, movement was not as common after 1998, perhaps suggesting that the effectiveness of habitat corridors for dispersal peaks earlier for small mammals than other species due to lack of immediate settlement and colonization by predator species. Nonetheless, two hybrid individuals were detected in the last year of sampling, indicating potential of corridors for re-establishment of gene flow between small mammal populations. Overall, this study reveals the efficacy of genetic analyses in monitoring animal dispersal and demonstrates that planted corridors may be able to restore small mammal movement between previously connected habitat.

10. **Targeted reforestation could reverse declines in connectivity for understory birds in a tropical habitat corridor**
    Habitat connectivity for birds in planted stands was estimated within the San Juan-La Selva Biological Corridor (2466 km^2) in the Caribbean lowlands in Costa Rica. This corridor connects Braulio Carrillo National Park and Indio Maiz Biological Reserve and includes a mix of private lands and wildlife refuges. Forest protection and tree plantation projects were implemented in the region beginning in 1996, but the effectiveness of these measures is thus far unknown. The impact on four understory insectivorous bird species (*Myrmeciza exsul, Henicorhina leucosticta, Thamnophilus atrinucha, and Glyphorynchus spirurus*) was modelled using data on movement and behavior across various types of habitat boundaries collected at 23 field sites in the Caribbean lowlands. Using information on bird movement preferences and land cover maps, GIS models of habitat connectivity for these bird species were created. Analysis found that functional connectivity declined from 1986-2011, and the highest rate of fragmentation occurred between 1996-2005, despite plantation efforts introduced in 1996. A slight increase in connectivity between 2005-2011 provides hope that forest conservation policies ultimately slowed the rate of habitat connectivity loss, but a complete recovery was not observed. More optimal selection of sites for protection and reforestation has the potential to increase functional connectivity in the model (by ~2%) and should be considered in future conservation efforts.

Conclusions and Recommendations

These studies provide a wide breadth of information on how various types of corridors, including underpasses, overpasses, and reforested areas, can serve as effective and useful wildlife passages for a range of species. The relative efficacy of corridor measures depends heavily on the target species and primary aim, but several general recommendations can be made concerning optimal corridor solutions. Underpass construction has potential to be effective in maintaining connectivity and reducing vehicle collisions, and should focus on abundance and variation in size, shape, and environmental conditions to account for the widest variety of species. Overpasses are overall a less effective measure in maintaining population movement and should be considered secondarily to other corridors, but may provide some use after a specified habituation period. Planted and reforested passages at targeted, high priority locations are useful as travel corridors and may increase habitat and population connectivity for some species. Overall, more studies must be conducted, especially those comparing wildlife movement and connectivity before and after construction of corridors, to truly understand the relative capacity and success of various corridor types. Future monitoring should include a combination of camera traps, infrared sensors, track pads, snow tracking, animal trapping, genetic analyses, and computer modelling depending on the goal of the study or surveillance program.

Supporting Studies

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