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<u>Conservation Evidence Summaries: Creating Wildlife Corridors to Influence Animal Dispersal</u>

Key Messages:

- Wildlife crossings appear effective at assisting animal dispersal, as target species are largely recorded using crossings. It may be that they're assisting the most with aiding the movement of species that are already the most abundant in study regions
- Wildlife corridors appear to direct animal movements, and wildlife species move more between connected than unconnected habitat patches
- Culverts in mountainous regions pose a significant barrier to movement and passage of local fish species. The most common, cost effective solution to fish passability problems in steep terrain will be building bridges or open bottom arch crossings in strategically selected locations.
- Forest birds use corridors to move more frequently than clear cuts, and corridors allow birds to maintain their movements at rates similar to those observed in undisturbed areas.
- Ringlet butterflies move between woodland clearings via grassy tracks, as they act as conduits between habitat patches. Connectivity would be significantly lower without grassy tracks.
- Lemur species use overpass "lemur bridge" crossings in areas of significant habitat disturbance, although it takes some time for them to fully utilize the crossings
- Mammalian nest predators are more abundant in greenways with wider trails and narrow forest corridors surrounded by mature, streamside forests
- Small mammals use wildlife crossings at ski resorts, and they're likely to aid their movement. These crossings can even become part of mammals' home range with time.
- The best possible locations for wildlife corridors to aid animal dispersal across highways are far from other existing crossing structures and between large forested areas.
- Constructing tunnels for cars may be the most effective infrastructure to aid the movement of Giant Pandas in central China

Background Information:

The movement and dispersal of wild animals has been impeded and, at times, entirely prevented by human development and encroachment on wildlife habitat. Roads, infrastructure, and destruction and fragmentation of habitats can have significantly adverse effects on wildlife populations (Borda de Agua *et al*, 2011; Lechner *et al,* 2017). As habitat fragmentation increases, wildlife movement across landscapes declines (Brook *et al*., 2008) Wildlife populations are largely influenced by localized population extinctions in habitat patches and dispersal patterns between patches (Hanski, 1998). Animal dispersal helps repopulate habitat patches, regulate local population dynamics, and reduce species' risk of extinction (Bowler & Benton, 2005). Wildlife corridors, whether physical infrastructure, such as overpass crossings and culverts, or the reforestation/replaning of habitats, can improve wildlife dispersal and movement. The degree of improvement will likely vary depending upon various factors, including targeted species and their respective life stages, corridor type, and surrounding environmental conditions. The design of wildlife crossings can affect which species use them, and the extent of how much they aid dispersal.

Supporting Evidence from Individual Studies:

1) In Gryz & Krauze-Gryz (2016) the researchers are primarily concerned with how expanded road development may collide with ecological corridors in Poland. They examine the S7 expressway, near Sucha Village, in one of Poland's main corridors: the South-Central corridor that includes the Pilica River Valley. Shortly after a wildlife passage was built, it was monitored to see how many medium and large-sized animals were using it, and how quickly after its construction they began to cross it. The overpass is approximately 4 km from the river valley, surrounded by open areas and forests. The structure is 50 meters wide and 225 meters long, and is about 400 meters from the nearest village. There are no guiding features associated with the overpass. The overpass was checked by two researchers approximately every two weeks from Nov. 2008-April 2009, where all tracks cutting the line at the top and bottom parts of the overpass were recorded. A total of 11 records were taken, consisting of 181 crossings by 11 mammal species. Red fox, European hare, and domestic dogs made up the greatest number of records, with the hare having the greatest number of records. The species making up most of the crossings are also the most numerous in the area overall. Other animals recorded include: moose, European badger, red deer, fallow deer, roe deer, martens, house cats, wild boar. Results indicate that animals used the bridge shortly after it was built. European hare used the bridge not only as a crossing, but a feeding place, consistent with other wildlife crossings in Europe. This study presents additional evidence that wildlife overpasses are being used by targeted species. The longer study length partly eliminated seasonality's influence on animal movement patterns. The corridor appears to be effective at assisting with animal dispersal, as most of the species potentially present in the area, including all ungulate species, were recorded using the crossing.
2) Haddad *et al.* (2003) examined how open-habitat patches and wildlife corridors created from harvesting pine forests would influence the movements of ten studied species. Their research was conducted at the Savannah River National Environmental Research Park near Aiken, South Carolina. The researchers established twenty seven 128 m x 128 m open patches, with some connected by a 32 m wide, open, variable length corridor. The ten species studied include: two butterflies (*Junonia coenia and Euptoieta claudia*), two small-mammal species (*Sigmodon hispidus; Peromyscus polionotus*), four plant species (*Ilex opaca, Myrica cerifera, Phytolacca americana, and Rhus copallina*), one bee species (*Xylocopa virginica*), as well as pollen of one plant species (*Passiflora incarnata*). Butterflies were studied through daily surveys of all patches from April to June, 1996, where each one was captured and marked. Adult *S. hispidus* were captured 13+ km away from the study site, fitted with radio collars, and released into one of the 10 different patches. Adult female *P. polionotus* were ear-tagged and introduced in next boxes in the center patch of each study block, and live trapping was done three days/week from May-August. Seed dispersal of the four plants was recorded through collecting avian fecal samples from seed traps positioned under perches for the

dispersing species; seeds were summed over an entire season. Pollination of *P. incarnata* was measured daily by marking flowers in a central patch with fluorescent powder, and recording the powder's presence on flowers in peripheral patches. Overall, of the ten studied species, five moved significantly more often between connected (versus unconnected) patches, including the two butterfly species, *P. polionotus, R. copallina*, and *M. cerifera.* For the rodent *S. hispidus*, the corridor effect on movement was not significant. For the remaining four species, corridors appeared to direct their movements, but results were inconclusive. This may be due to small sample sizes. The experimental corridors directed the movement of all ten study species, even when controlling for other factors unrelated to the corridors. For all species, 68% more individuals moved to connected than unconnected patches, leading to the conclusion that the corridor effect is generally significant. Furthermore, results suggest that emigration of the study species is not determined by landscape patterns. The study results suggest that corridors can be valuable tools for landscape-scale conservation for a variety of taxa.

3) Poplar-Jeffers et al (2009) examined how culverts influence the movement and reproduction of Brook Trout populations in the Upper Cheat River basin of eastern West Virginia, USA. The researchers used ArcGIS to determine all of the road-stream intersections in the 869 km of stream in the study area, and studied 120 state-owned culverts in the study area. From June to November 2003, they surveyed all of the included culverts in the study area to determine fish passage classification by examining specific aspects of each culvert, mean channel widths, and the topography of the stream above and below each culvert. The data were used to determine the "passability" of each culvert into three categories: completely passable, partially impassable, and completely impassible. All of the culverts violated at least two critical criteria for passability, and 97% were classified as obstacles to trout passage. Culvert passability was most closely associated with channel slope, and barriers to fish passage is an extensive problem in the study area, greatly impacting the area's fish communities. High culvert slopes contributed significantly to passage problems. Due to a lack of cost-effectiveness and the steepness of mountain streams, the most common solution to fish passability problems in mountainous areas will be building bridges or open bottom arch crossings. The researchers determined, through prioritization of an ecological currency (weighted potential Brook Trout Recruitment Area, or WPRA), that replacing only 20 culverts could reconnect almost 50% of isolated Brook Trout reproductive habitat. This suggests that strategic watershed-scale restoration can be done in a cost-effective way
4) Machtans et al (1996) conducted a three year field study to measure the response of songbirds to clearcutting of boreal forests near Calling Lake, Alberta, Canada. They measured the movements of birds before and after clear cutting activities to measure their movements through riparian buffer strips.The researchers set up lanes of eight 12x2m mist nets along the entirety of the understory of each buffer strip, from riparian to clearcut edge from 1993-1995. One site was monitored before and after harvest, and three were monitored after harvest from the end of May to the beginning of August of each study year. Captures of adult and juvenile birds were considered separately, and the first netting sessions were excluded from statistical analyses. The nets were checked

every 15-20 minutes per six hour study session. Age, sex, species, location and time of capture were recorded, and birds were banded. Visual observations of birds in clearcuts were made to determine avian movement through them. The ten most frequently recorded bird species in the mist nets were observed significantly less frequently in the clear cuts. Thirty five species were seen in clearcuts, but only five of them made up ~65% of observations. Most of the captured adult birds were likely residents of the buffer strips, providing evidence for their conservation value as a place of wildlife residence, not just as fosterers of movement. Only two of the ten most frequently captured forest species used clearcut areas for nesting and foraging. Juveniles did move more frequently in buffer strips post timber harvesting than prior to harvest, suggesting the strips act as corridors for juveniles. There was also more movement within buffer strips than at control sites (lakeside forest with no adjacent clearcuts) Overall, their findings indicate that forest birds use corridors to move more frequently than clear cuts, and corridors allow birds to maintain their movements at rates similar to those observed in undisturbed areas.

5) Sutcliffe and Thomas (1996) conducted a mark and recapture study of Ringlet Butterflies *(Aphantopus hyperantus)* at the Monks Wood National Nature Reserve in Cambridgeshire in eastern England from late June to early August, 1994. Butterflies were marked using color coded dots on their wings. They calculated exchange rates between pairs of patches, measured distances between patches, and carried out three hour long behavioral observations where the butterflies were tracked until they left a defined study area within a glade. The study's results suggest that adult *A. hyperantus* moves between woodland clearings via grassy tracks, rather than through the trees, as they rarely entered dense woodlands. Overall, connectivity would have been significantly lower without corridors. It appears that the grassy tracks act as conduits between fields and glades for the butterfly in the study area, allowing the species to move between patches as resource availability varies. Increased connectivity could reduce the rates of local extinctions of *A. hyperantus*, or help them recover in areas of localized extinction.
6) A nickel mining project in eastern Madagascar, near the town of Morammonga, sought to mitigate its environmental impact by installing seven 'lemur bridges' along roads and pipelines in the mining area. Mass *et al* (2011) studied the effectiveness of these road crossing structures through monitoring the lemurs crossing them. First, bridge installation sites were determined by monitoring roads and the pipeline in the mine area for 14 consecutive days to see where animals were crossing. The locations of lemur crossings and crossing attempts were mapped using GIS, and three main areas were deemed potential sites for bridges. Ultimately, sites were located based on crossing frequency and habitat quality. Two different bridge designs were installed at the costs of $3,000 and $500 USD, respectively. After installation, the crossings were monitored during the day from March 2009 until August 2010 for ten hours a day for 4-6 days per week, for a total of 7,640 observation hours. For each observation day, bridge crossings, road crossings, and lemur presence without crossing was recorded. The presence of vehicles and human pedestrian use of the roads was also recorded. In total, six lemur species were observed crossing the bridges, and species crossing the bridges from 2009 to 2010 increased from four to six. The lemurs used the road bridges more often

than those along the pipeline. As of the time of the study's publication, more diurnal lemur species used the bridges than nocturnal ones, but that may be due to a lack of nocturnal sampling. While lemurs can cross roads, the use of relatively low cost bridges has a positive result on their dispersal, as they prevent accidental collisions between lemurs and vehicles.

7) Sinclair *et al* (2005) examined how the abundance of mammalian predators of birds' nests may be influenced by greenways in Cary and Raleigh, NC, USA. Specifically, they looked at the width of forested corridors, adjacent land use classes, and a greenway's habitat structure. They used aerial orthophotographs, and digital land use and zoning maps to select sampled greenway segments, which were 300 meters long. A total of 34 study segments were selected over a variety of corridor widths and landscapes, and each were treated as independent samples. Adjacent land use classes were defined as low density residential, high density residential, and office/institutional. Five scent stations with a bait consisting of a cotton ball soaked in fox urine were placed 50 meters apart along a transect through each forest corridor to measure the relative abundance of mammals within each greenway segment. Stations were set up in the morning, and then wildlife tracks were recorded the following morning for two consecutive nights once every month from May-July. They also recorded elements of habitat structure thought to affect mammals, including the width and types of trails within greenways, forest type, proximity to water, forest structure, and if there were non-forested areas within or next to the greenways. At least nine mammal species were documented in the greenway segments, with at least one nest predator detected in every study segment, with cats and racoons being the most abundant nest predators. There were significantly more nest predators in greenways with narrower forest corridors, with the smallest numbers recorded in greenways over 200m wide. Areas with more buildings in the surrounding landscape had lower abundances of nest predators. There were most nest predators in areas with more mature forest, ground cover, and wider trails. Overall, nest predators were more abundant in greenways with narrow forest corridors, and in areas with more mature, streamside forests Areas with wider trails had more nest predators, as they may use them as travel corridors.

8) Sato and Schroder (2017) conducted research to find out if and which small mammals are using wildlife crossings located on ski runs at ski resorts, and if structural differences in crossing size influences which species are found using them. The study was conducted in southeastern Australia at the Perisher Ski Resort located in Kosciuszko National Park. Eight monitoring sites were set up between 1600 and 1850 m elevation at short (<16m) and long (>30m) boulder-filled wildlife crossings that connect remnant vegetation. They surveyed small mammals using 342 hair tubes placed every 3-6m along the crossings, baiting animals with a mix of peanut butter, oats, and honey. The tubes were left in place and collected after seven days. Crossings were surveyed every winter and spring from March 2009 until April 2013. Two under road culverts were also monitored in Dec. 2012 and April 2013 for seven days by using infrared automatic cameras triggered by animal movements. They detected every small mammal known to reside in the subalpine zone in the crossings except for the agile antechinus. Mountain Log skinks, Southern Water skinks and Bogong moths were also recorded using the

crossings. Images from the under culvert crossings indicated that animals were moving back and forth through them, with peak activity during the early morning and mid afternoon. Different species were found at short and long crossings, suggesting that the length of boulder filled crossings may influence the types of species using them. Overall, small mammals use wildlife crossings at ski resorts, and they're likely to aid their movement, and can even become a part of mammals' home range with time.

9) Gurrutxaga and Saura (2013) prioritized locations for wildlife corridors over a region encompassing 7,521 square km in the Basque country of northern Spain. The examined spatial information on the region's land use and highway infrastructure to perform a landscape connectivity analysis, focusing on a generic group of forest mammals that are sensitive to highway barriers. They produced a generic resistance map that outlined the least-cost paths between all of the map's node pairs in order to propose locations of defragmentation measures at the potentially most suitable sites across the study region. Ultimately, two maps were built to assess the benefits of each possible location for defragmentation infrastructure, and they identified 11 locations for the construction of wildlife overpasses. Two locations located far from other existing crossing structures and between large forested areas were determined to be significantly more effective at promoting wildlife dispersal.
10) Wang *et al* (2014) evaluated a framework for forest corridor planning for the giant Panda by studying a 400 square km area in the Xushui river valley in the Qinling mountains of central China. They surveyed giant pandas using a combination of infrared cameras operating 24 hours a day and tracking through feces, animal tracks, and signs of feeding at 243 plot locations from April 2010- March 2013. They mapped the habitat suitability for the entire study area, and their least-cost model generated two potential movement corridors of 17km and 40km in length, and 2km and 1km in width, respectively. Their results found giant pandas near small home residences, suggesting that limits on building size could be implemented in wildlife corridor areas. Furthermore, the pandas were found in low elevation sites, which contradicts other studies indicating pandas found at higher elevations. The researchers suggest that constructing an automobile tunnel may be the most effective measure for removing barriers to giant panda movements.

Conclusions and Recommendations:

Overall, wildlife corridors appear effective at assisting with animal dispersal, and they can direct animal movements. However, wildlife corridors do not affect all wildlife species in the same ways, and wildlife response to corridors is likely to be species specific. A corridor that aids one species may even impede another's movement. Thus, corridors may need to be designed to target specific species. (Sutcliffe & Thomas, 1996). Furthermore, target species may take up to several years to start using new crossing structures (Mass et al, 2011). Seemingly simple solutions, such as limiting high density development near greenways, without further habitat management may have little effect on the movement of wildlife species. Ultimately, natural resource managers must aim to balance habitats to promote multiple wildlife management objectives. Threatened small mammal species found in disturbed alpine environments make use of wildlife crossings. However, without additional conservation measures, species are not likely to persist (Sato and Schroder 2017). Ultimately, creating wildlife corridors is not enough. Multiple, complementary strategies must be employed together to offset development disturbances to wildlife. Human infrastructure should be considered in conservation planning for wildlife. Corridor creation can be prohibitively expensive but, when done strategically, significant gains can be made for wildlife in a cost efficient manner (Machtans et al, 1996; Poplar Jeffers et al, 2009). For instance, integrating corridor creation into timber harvesting or road development plans can significantly reduce costs and planning time. But, if corridor planning is not based on sound, quantitative information about species-environment relationships, there is little practical value in it (Wang et al 2014). Since funding for wildlife conservation is limited, it's essential to establish the relative contribution each proposed corridor will have on aiding animal dispersal and maintaining habitat connectivity.

A number of future studies could further our knowledge on the effectiveness of wildlife corridors in facilitating animal dispersal. For one, there's a need for more studies that monitor the presence of targeted species before and after wildlife crossings are built to account for pre-disturbance populations, and to see if population changes and dispersal patterns are in fact due the new infrastructure, or other factors. In this era of unprecedented climate change, more research needs to be done on how crossings can aid animal dispersal as species migrate into new environments. Studies that examine the nuances of crossing design could prove useful to see which structural elements are the most beneficial to wildlife.

Supporting studies:

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2) Bowler, D., & Benton, T. (2005). Causes and consequences of animal dispersal strategies: Relating individual behaviour to spatial dynamics. *Biological Reviews, 80*(2), 205-225. doi:10.1017/S1464793104006645
3) Borda-de-Água, L., Navarro, L., Gavinhos, C. *et al.* Spatio-temporal impacts of roads on the persistence of populations: analytic and numerical approaches. *Landscape Ecol* 26, 253–265 (2011). https://doi-org.proxy.lib.duke.edu/10.1007/s10980-010-9546-2
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