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Conservation Evidence Summary: Population Abundance
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Action: Creating corridors to influence biodiversity

Key Messages:

- **Ten studies** evaluated the effects of implementing green corridors on the biodiversity and abundance of species.
- **Five studies** evaluated major motorways and highways where species are found to have very high mortality rates. (Studies: 1, 3, 4, 8, 10)
- **6 studies** evaluated dry grassland or forested areas. Many studies are successful in these areas as it is easier to track and observe species using the corridors. (Studies: 1, 4, 6, 7, 8, 9)
- **1 study** evaluated a marine environment. Marine environments are particularly difficult for measuring progress as well as making determinations to design and built corridors. (Study 2)

Background Information

Earth's natural habitats have been increasingly fragmented due to human development and activity. Not only are habitats destroyed for development of cities, but in many areas agricultural landscape has left only small patches of natural land (Hilty *et al.* 2006). The loss of natural habitats has caused a great loss in biodiversity on Earth. Over the course of 400 years of human development and expansion, roughly 250 species of reptiles, mammals, amphibians and birds have gone extinct. At this point in time over 11,000 species of animals and plants are at risk of being lost to human activity. The goal of creating corridors is ultimately to protect and increase biodiversity of plants and animals. The main factors for conservationists to consider is where to look, and how to implement a corridor effectively (Sanderson 2003).

This section consists of an in depth look at the effects of corridors on population abundance, which refers to the representation of a species within a certain ecosystem (Farmer 2011). Recent studies show that introduction of corridors to fragmented habitats has a significantly positive effect on population structure. Corridors can be effective for terrestrial species both on the ground and those with flight, as well as marine species. Habitat maintenance may be required for certain areas with rapidly growing vegetation, or areas where plant life is essential to success of a population. Some studies analyze whether or not the type of corridor makes a difference, and which is best, while others observe the overall effect of corridor implementation on the survival rate and success of the species.

There are cautions to these studies, as many have a mesh or grate covering for corridors to reduce increased predation on the animals using them. Overall these studies have been successful in not only having improved results, but replicable ones as well. Testing measures can be done through laser, photo imaging, footprint analysis in sand or on inked paper, as well as live trapping. Catching animals in the following studies was done without killing the animals of study. Overall this method to increase population abundance and population density is very successful. Many studies saw a significant increase in success of population due to measures taken to conserve both small and large species.

Supporting Evidence from Individual Studies

1.

This study examined the network of motorways in Austria, looking specifically at the ability of wildlife to permeate the motorways which were largely fenced off (Woess 2002). Large wildlife was the main focus, as they need the largest area to pass across a motorway. The study was split into two projects, the first regarding permeability of passageways and the relationship to width, and the second examined genetic interchange between populations with existing and new corridors. The first study provides a map of the forests, motorways and important migration corridors of the large forest species in lower Austria. The second study was located in the connecting belt of the Carpathian Mountains and Alps. Both projects looked specifically and forest ungulates and large game, which includes red deer, roe deer, wild boar, chamois, brown bear, moose, lynx and wolf. Motorways and their passageways for animals were categorized into five groups: width type A (≥80m; for game species), B (≥30m; all game species), C (≥15; small roe deer and furred game), D (≥6m; small furred game and some roe deer), and E (≥3m; small furred game). Using aerial imaging and database analysis, the study measured appropriate sizing of passageways for animals based on animal size and motorway type. A "minimum permeability" number was given to each motorway based on international, regional, and local defragmentation assessments. Additionally, land mapping and aerial image analysis were implemented to provide information on the landscape and corridor regions, and wildlife observation, questioning hunters and trail surveys provided the study with population abundance data. Results of the first project created a system for building corridors that would effectively allow passage of large forest game. Passageway type A is recommended for corridors with international relevance with a minimum width of 80 meters, passageway type B is for sensitive species and requires 5 corridors at 30-meter width across the motorway, and passageway type C is for local habitat defragmentation requiring 5 corridors at 15-meter width. Both studies showed that implementation of these methods insured long term continuation of genetic exchange, which was previously decreased due to motorways and human activity.

2.

This study examines benthic wildlife corridors and the improvement of biodiversity through ecological connectivity (Krost 2018). The area of study has undergone vast changes to marine habitats over the past 150 years, including a decrease in area of the Inner Fjord, decrease in shallow habitat, topography changes, loss of hard substrate, and a paved and sealed waterfront. This study aims to mitigate these changes with wildlife corridors, which would improve the marine ecology while human activity continues. The study takes place in the Inner Kiel Fjord, Germany, which hosts a large amount of human marine activity (shipping, navy activity, beaches). This study examined *Zostera marina, Fucus vesiculosus, Syngnathus typhle, Entelurus aequoreus, Nereis pelagica, and Delesseria sanguinea.* They also considered biotope environments on a broader scale. Connectivity of these biotopes would increase the range and movement of species within each disrupted habitat. They first categorized the biotopes within the region, then found connecting variables within each to best place connections in the Fjord (water depth, sediment type), and then used GIS processing to make sure connectivity between biotopes would be possible. After data was collected, this study implemented measures for best connectivity of most important of the marine species (dispersal range was a key factor for both larval and adult stages of species). The final stage was to reconstruct biotope conditions to how they were before industrial activity took place, taking into account conflicts with current structures and activities. The benthic wildlife corridors would consist of restoring and reconstructing habitats, which may include linear patches as well as corridors. The preexisting biotope categories are defined and mapped, and within each biotope species are identified for their type as well as range of movement. The last step in this study's procedure is to reconstruct their range based on current and past conditions to be as natural as possible for their mobility. Reconstructing and connecting biotopes through corridors and patches were used to improve migration of animals, increase genetic interchange, which increases population abundance. The study shows a comprehensive set of data recording their results. These outline the classifications of biotopes and habitats, which resulted in 11 categories. They include the most relevant species to their project and their range of movement and mobility, as well as distribution potential. The outlook of this study shows that their multistep process for rehabilitation of these marine areas does improve marine biotopes and increases diversity.

3.

This study examines a practical approach to assess habitats and connectivity of species to produce effective green corridors (Zhang 2018). They note that natural green spaces have become increasingly smaller, which negatively affects population abundance, genetic variation and species richness. This study provides a method enhance ecosystem connectivity by using corridors to link existing green spaces, looking specifically at highly urban areas. This study was done in the City of Detroit, where they implemented, refined, and evaluated their methods to increase connectivity using green corridors. This study did not look at any species in particular but based on models and analysis of variables; they noted that this study would not be as effective for tree-dwelling animals. They use green corridor designs tested in Detroit, Michigan to improve landscape connectivity. First, they look at connectivity of urban green spaces using FRAGSTATS software, which then allows them to prioritize areas in need of a corridor that will be best suited and most successfully implemented. The last step is to introduce designs specific to the green space location to make connecting corridors. After analysis of the urban green spaces the corridors could be introduced. There are certain factors which contribute to designs for specific locations within the city. Their method to facilitate and improve the movement of species was to use a networked green space; this would connect various small natural patches within the city to allow for increased movement of species and genetic diversity. In this study they note that increased connectivity between urban green spaces would lead to increased species abundance, richness and diversity. They found that in every area which they tested, connectivity using their methodology of building and placing was effective. There was a city-wide increase in functional connectivity of 10.25%. Further analysis shows that development of corridors in high-priority areas increases connectivity and thus movement of species within the city.

4.

This study examines the effects of urbanization, specifically road building impact, on biodiversity (Bond 2008). In this study they took observations and data on a road that had been increased from a two-lane road to a four-lane road. Over the course of four months they monitored roadkill, and for another 6 months following that researchers on the project took data and observation on two underpasses and one overpass which had been built for conservation. Data was taken in the suburbs of Brisbane, SE Queensland around the Karawatha Forest, during a period of prolonged draught. Species involved in this study were various rat species, as well as red necked wallaby, swamp wallaby, eastern grey kangaroo, and brown hare. In this study they built two fauna corridors underneath Compton Road, which were 2.4 meters high, 2.5 meters width, and 48 meters long. Each corridor had three sections, one for water flow, one with rock ornamentation, and the other with wood and logs. Minor adjustments to corridors were made for smaller species to be able to reach the passage sections. There was also a land bridge put above the road, which was in the shape of an hourglass, at a length of 70 meters, edge width of 20 meters and central width of 15 meters; it lies 8 meters above the road and has 5.4 meters of clearance. Layers of shrubs and vegetation cover the overpass to provide wildlife with a natural appearance. This team used a methodological approach to implement and monitor the outcomes of these corridors. Initially they monitored roadkill to find the most negatively affected area on the road, and after implementing corridors designed specifically for the mammals crossing these were put in place. They monitored animal movement through the corridors using sand tracking, scat collections, and roadkill surveys. Many small species were found in the underground corridors; initially they found 1-5 tracks in each underpass per day, but these increased steadily as time went on (peak at 42 tracks in one day). In Table 2 of the study they show numerical differences between the first period of observation and the second; these show that on average there was a significant increase inn number of crossings per day using the under and overpass.

5.

This study describes the importance and specific functions of corridors, but more importantly they created a checklist to use to evaluate corridors for maximum effectiveness (Beier 1992). This study does not specify a location as such but does a wide range of analyses on other literature to compile this checklist. Within it does include a variation of explanations and examples of different habitats, including but not limited to deer and cougar, with varying vegetations examples. One note is that this study deal in particular with terrestrial species. The methodology of this study includes a brief explanation on corridors and their importance and goes in depth on their checklist to evaluate corridors. The checklist includes 6 steps. The first is to identify which habitats are needed to be connected through a corridor based on highest need, most important species, or protected status. Step two is to define species of interest which are present in the areas, which will allow for more specific designs of corridors. The third step is to evaluate needs of each species, which again, will aid in the design and structure of the corridors; this includes understanding movement, range, and seasonal patterns. Step four is to evaluate how much the corridor will actually facilitate movement for the species of interested, in other words, the effectiveness of the corridor. The fifth step is to put corridors on the map so that best linkages are made in a given area. The final step is to design a monitoring program which may count tracks, document with photography, or measures of gene flow. This checklist optimizes corridor implementation in an area for best possible results. The study acknowledges that more effective corridor leads to increase in passing genes between species previously separated by human activity. They suggest that corridor length and design is just as important as topography and vegetation of the corridor.

6.

This study involves the study of the decline and rise patterns of badgers over an extended period of time in one area (Vink 2008). Analysis of the population's periods of rise and decline show how badgers respond to human activity and development and suggest that use of corridors has a positive impact on badger populations. They suggest that not only can corridors extend their life span but allows badgers to disperse and colonize new areas. Lower death rates due to corridor use increase population abundance and biodiversity within the population. Data was collected from a local population of badgers in Eindegooi, which lies in the Dutch province of Utrecht and Holland. This area is densely intersected with roads and railways. This study looks specifically at the European badger *Meles meles*. Data was collected on this population of badgers over 24 years. The badger populations in the area are separated by about 30km on average. The team doing this study counted badgers, both adults and young, and gave detailed descriptions several times per year. They also searched for badger setts (dens), as well as roadkill. Once tunnels and corridors were put in place under the roads, volunteers studied movement through them using barbed wire and footprint beds. Throughout this study they had put in 14.2 km of fence, and 27 tunnels. Observation of the corridors shows that badgers used them almost instantly upon implementation, and about 50% of corridors were used. Additionally, over the course of this study the badger population in this area increased from six individuals to 91, which shows a significant increase in population abundance due to corridor use.

7.

This study aims to show how corridors connecting isolated patches increases density of butterfly populations (Haddad 1999). They were able to connect isolated habitat patches using corridors. The purpose of this study was to demonstrate how use of corridors would increase the population abundance and density of several species of butterflies. The experiment was located in the Savannah River Site in South Carolina. There were four species observed in this study: *Papilio troilus, Junonia coenia, Phoebis sennae, and Euptoieta Claudia.*Corridors were made using materials to significantly contrast with the surrounding pine forest and were "open" structures for butterflies to fly through. The patches and corridors used in the study were open habitats, with a total of 27 equal sized patches and 19 corridors. Each corridor was 32 meters wide and ¼ width of the patch size. The team used laser transit to monitor butterfly activity in each patch. They used grids marked with chloride pipes on each corder of the patch. Using analysis and observational data they found butterfly densities to be on average at 8-meter intervals. They took butterfly surveys as well as vegetation surveys and used statistical analyses to organize their data. Results of their analysis shows that population densities of three of four species had increased in patches that were connected by corridors. An X^2 value of 38.03, P = 0.001, and df = 6,137 show that *J. coenia* was dependent on corridor use for increase in population abundance in the area. Other factors this study considered with each corridor and patch was the flower and nectar type of the patch and corridor. Graphs within this study show how population abundance was positively correlated with plant species, and that corridors positively affected species abundance at peak seasonal times.

8.

This study observed the effects of corridor implementation on a mountain pygmy-possum population structure after human activity fragmented their habitat (Mansergh 1989). Development of a ski resort lead to the decline in this small marsupial population, so this group put two tunnels beneath a road in hopes of increasing population and survival rates. This study was located oon Mount Higginbotham in southeast Australia, and the species observed in this study was the mountain pygmy-possum. This group placed a funnel shaped corridor on one of the slopes which had been altered by the ski resort, which consisted of basalt rocks. The other two corridors were placed underneath the road with dimensions 0.9x1.2meters. The corridors connected a breeding area that had been bisected by a road. They also place mesh grills on both ends of the corridor to ensure that the pygmy-possums would not have higher predation rates from corridor use. This study analyzed the number of individuals per age class and sex that passed through between the bisected breeding areas. The results from their observation and analysis after corridor implementation show that before the corridors were in place, juvenile and adult males did not disperse during non-breeding times, but they were actively moving once the corridors were in place. Because there was a trapping period during the season, they measured that trapping of the pygmy-possum decreased from 25% to 10% once the corridors were in place. Additionally, studies showed that female survival rate in areas disturbed by human activity increased from 57% to 96%. Photographs from cameras installed within the corridor showed that pygmy-possums were using the corridors within two weeks of their placement, and within 90 minutes of camera installation.

9.

This study looked at how increasing landscape corridor width and overall presence would affect population dynamics on the meadow vole (La Polla 1993). The initial purpose was to find out how vole populations reacted isolated small patches of habitat versus small patches connected by corridors. They also analyzed the movement response of voles with either varying corridor width versus simply corridor presence. This study was located in a 2.5-ha field community that had mostly goldenrod and alfalfa at Miami University Ecology Research Center in Oxford, Ohio. The target species in this study was *Microtus pennyslvanicus*, or the meadow vole. They used a 3x3 block design and treatment in two, 20x20 meter patches which were either connected or not connected through 10-meter long corridors. Patches were 400 square meters, and voles released went into the source patch, leaving empty patches called sink patches. Some corridors were 1-meter wide, while others were 5-meters wide. This study required weekly maintenance of corridor surrounding vegetation. Once the habitat and corridors were in place, they used live trapping to identify which voles were dispersing and which were residents. Additionally, tracking of voles through the corridors was done through tube data, as well as white paper with black powdered paint for vole tracks. Results showed that there was no difference between source and sink patches for vole densities, but each treatment of the patch increased the population density significantly. In just one month the cover density increased from 209 to 236.5 in just one month in the control patch, increased from 218.3 to 250.3 in the narrow corridor, and increased from 222.2 to 272 in the wide corridor. These results showed that the mere presence of a corridor positively affected population structure and vole abundance, but the width of the corridor made no significant difference.

10.

This study consisted of the placement of a wall-culvert barrier system due to high death numbers of wildlife on a highway (Kenneth 2004). Wild animals were killed on the highway due to rapid vehicle speeds, high traffic volumes, local topography, little cover to animals, and structural features on the road. This experiment observed the effects of corridors under this highway between large wetlands. The location of this study is Paynes Prarie, which is a large highland freshwater marsh in Alachua County, Florida. This study analyzed and observed reptiles, small mammals, and amphibians. They monitored roadkill prior to the construction of the corridor, as well as after, mostly looking to see if animals were using ecotones as corridors before theirs was built. Roadkill surveys were done by one to four people walking up and down a 3.2 km stretch for roadkill on every side of the highway. They also monitored culverts for wildlife usage. This group used preexisting culverts, as well as adding four new culverts to be part of their wall-culvert barrier system. One culvert was wet, while three others were usually dry, but these depended on local water levels; culverts had earthy substrate inside of them. The built culverts were 1.8x1.8 meters, surrounded by various trapping mechanisms to trap and record movement through both the new and old culverts. Results show that mortality of these wetland species significantly decreased following the building of more culverts. Followig the barrier wall-culvert system they found 1891 dead animals on the road, compared to pre-construction 2411 deaths in one year. 1647 of these were frogs, one alligator, seven turtles, four lizards, 149 snakes and 83 mammals; overall this was a significant decrease to the previous year before construction. 73% of road kills (not including frogs) were found in areas outside of the range of the wall-culvert system. Overall mortality decreased and population structure was positively affected by the introduction of culverts and barriers on the highway.

Conclusions and Recommendations

Overall, using corridors is a successful method to increase population abundance in mammals, amphibians, reptiles, and birds. Corridors do not affect all species equally, for example, frogs mortality was not significantly decreased when corridors were placed underneath a highway. However, small and large mammals see a positive effect from corridors, as well as butterflies. Based on these studies it is difficult to determine which type of habitat is most successful, but certain methods of implementation proved more successful than others. Measures which found success were often those with careful construction of corridors that were well fit to the specific species under observation. Additionally, maintaining vegetation well suited for the certain species is crucial for success of the animals moving through the corridor. A more difficult area to study is marine environments, as many factors are at play there; understanding high priority and cohesiveness of marine animals and environments is crucial to making corridors underwater. Additionally, land use in urban areas presented a different problem than did more open, agricultural areas. Urban green space is very limited, so it is important to have a good grasp on where to make linkages between them. One study suggested that using vacant land and network connectivity in high priority areas was most successful. When examining whether or not a corridor is successful one could use the 6-step checklist, as well as methods of measuring minimum permeability to see where corridors are needed most in an area of migration. The main takeaway from this analysis of various studies is that corridors do help improve species abundance, richness, gene diversity and population density, if design and implementation measures are done thoughtfully for each species.

Supporting Studies

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