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Creating Corridors to Influence Biodiversity and Community Benefits

Key Messages

- Three individual studies (numbered 1, 2, and 3) investigated effects of restored and planted corridors across the Terai Arc Landscape of Nepal and India. The monitoring periods differ from one study to the other, making our inferences about TAL corridors more robust. All the three studies reported significant number of animals (especially tigers) using the corridors.

- Two studies (4 and 8) investigate the effects of corridors constructed over and under highways. Both the studies report appropriate usage of the underpasses/overpasses and overall mitigation in road accidents.

- Two studies (5 and 10) are based in Queensland, Australia. They mainly investigate the effects of constructed corridors on species such as the kangaroos along with few other incidental species.

- One study (6) relies extensively on qualitative data to understand the effects of constructed corridors and their better management.

- One study (7) uses only flora (different species of plants and trees) as a measure for success of the corridor project based in Madagascar, while using the same data to understand its long-term potential benefits.

- One study (9) assesses canopy bridges installed to facilitate monkey movement across forests in Brazil.

Background Information

As natural habitats continue to be lost to various types of economic development and landscapes are becomingly increasingly fragmented, environmental and land managers are having to rely on the ecological functions of corridors to conserve soil, air, water, fish and wildlife (MacDonald, 2016). Conservation or even new constructions of these resources provides benefits for not only flora and fauna, but also individual landowners and the larger community that relies on these ecosystems (Manjaribe et al, 2013). Therefore, anthropogenic corridors have become increasingly relevant to link the fragmented habitats with the increasing human activity surrounding habitats. The benefits of such corridors are immense – not just environmental, but also economic and societal. My hypothesis is that community benefits, such as environmental awareness, knowledge, skill, safety, social capital, cooperation, participation, ownership, basic need, and long-term social and economic sustainability, are enhanced with construction or restoration of forest and wildlife corridors.

Supporting Evidence from Individual Studies

1. The Terai Arc Landscape (TAL) includes 12 protected areas of Nepal and northwestern India. The landscape is surrounded by the Corbett-Rajaji Tiger Reserve complex of India to the west and Chitwan National Park of Nepal to the east (Wikramanayake et al., 2010). In Nepal, bottlenecks

were identified for restoration along potential tiger corridors. The major restored corridor runs along the Churia hill range, while others connect the Churia hills with protected areas in the Terai. The main roles of the TAL program were to identify strategic areas in bottlenecks for restoration and secure peripheries from further deterioration, act as an intermediary between the Forest Department and Community Forest User Groups (CFUG) to hand over the strategic community forests to the user groups, strengthen the user groups to enable them to manage the forests, and raise awareness and promote sustainable livelihoods. As a result, within a span of five years, 22,000 ha of community forests were handed over to 200 forest user groups, comprising of 29,000 households. The user groups were coordinated through committees that represented the interface to the project and also supported other functions such as community-led anti-poaching groups. The TAL program also provided subsidies to the local communities to build biogas plants, which improved fuel-efficient cooking stoves. This activity helped save an estimate of 21,000 metric tons of fuelwood annually from 2001 to 2006. This fuelwood saving was equivalent to 162 ha of clear-felled forests. Consequentially, this program was officially hailed as a 'gold standard' Clean Development Mechanism project because of the carbon savings it brought forth. However, the above was not the only or major driving force behind community enrollment into corridor construction and conservation. The Churia Hills, mostly forested, and the rivers that flow from the range provide the water necessary to sustain community lives and livelihoods in the region. Degradation or removal of the Churia range forests can potentially results in disastrous consequences to not only the local communities but also to the national economy. Aware of this, Government of Nepal and the local communities willingly protect the forests in most areas. The success of the corridor restoration was assessed on the basis of wildlife usage – especially the tigers. Within the five years of monitoring period, tigers were detected in four corridors still undergoing restoration. Tiger presence was found to be more frequent in the Khata corridor during the winter months than summer or monsoons seasons. According to the qualitative reports from the communities and forest monitoring units, prey species in Basanta area and community managed forest have been increasing. In 2005, a camera-traps used by the WWF and the park staff from the Suklaphanta Wildlife Reserve revealed the presence of 17 tigers. In 2006, five new tigers were photographed in the camera trap locations, while only 10 of the 2005 animals were photographed. Given that tigers are territorial, the five new tigers were possibly transients or new residents. This suggests that there has been considerable immigration of emigration of tigers to and from the reserve. Even through camera trap monitoring was still limited, evidence was found to prove that the corridor was not limited to just tigers. Elephant presence increased in four corridors, including the Lamahi corridor, where they were absent for approximately 50 years. Greater one-horned rhinoceroses were detected in a transbounfary corridor that links Suklaphanta Reserve to a set of Indian forests and were also found in the Khata corridor that links Bardia National Park in Nepal with Khaterniaghat Tiger Reserve in Indiad. At least five rhinoceroses were reported to have been seen in Khaterniaghat, where there were none before.

2. In Nepal, conservationists have identified 20 landscapes with the great potential for long time conservation of wildlife (Thapa et al., 2017). However, these landscapes have increasingly become insular as the matrix converted to anthropogenic land uses. Tigers that are especially vulnerable to such loss and fragmentation inadvertently increased their presence in human-dominated matrices. This often causes fatal consequences for both tigers and also the

community that lives by these matrices. Therefore, habitat connectivity in the form of corridors to enable tigers to traverse the matrix with minimal is particularly important for both tiger-conservation and human safety. A study of the increase in tiger population between 2009 and 2013 in the Terai Arc Landscape, a critical tiger habitat in India and Nepal, proves that strengthening corridors between habitats can result in higher population growth than in two disconnected habitats. Specifically, using camera trap methods in the Bardia National Park, Nepal and the Suklaphanta National Park, Nepal and their corridors, the team estimated that the tiger population had grown 15% and 21% respectively. Without corridors, the tiger populations in these habitats were estimated to grow between 3% and 10%. Camera traps recorded 11 individual tigers over the course of the study indicating that access to Indian reserves improved Nepal's tigers' reproductive success. The data also indicates that access to protected corridors has resulted in tigers that are comfortable leading a transient existence between India and Nepal. The study offers strong evidence that establishing and strengthening corridors between isolated populations of a threated species can strengthen that species' population growth.

3. An assessment of the Khata corridor connecting the Bardia National Park in Nepal and Katarniaghat Wildlife Sanctuary in India indicates that the corridor is helping sustain and grow the tiger population in the parks and is also benefitting the adjacent human communities (Wegge et al, 2016). In 2000, the Nepal and India governments established the Khata corridor to allow for better mobility between the Indian and Nepalese tiger populations. To assess the tiger population, the team employed camera traps. Specifically, between 2012 and 2013, the team captured nine individual tigers in the corridor. Of the nine individuals, three individuals were captured in the Bardia National Park, while four individuals were also captured in the Katarniaghat wildlife sanctuary, thereby indicating healthy population mobility. To assess the impact on the adjoining human communities, the team assessed human wildlife conflicts such as livestock and human predation. Despite scat analysis showing that tigers in the corridor consuming a higher concentration of livestock than tigers in the core area of the Bardia National Park, livestock predation and attacks on humans actually decreased between 1998 and 2014 owing to better grazing regulation and higher natural prey populations. Based on interviews, the majority of residents in and around the corridor support the tigers and tiger conservation. Thus, an assessment of the Khata corridor indicates that holistic implementation of wildlife corridors can improve species' health and population, while also benefiting adjoining human communities.

4. Canada's Rocky Mountain front harbors the richest diversity of large mammals in North America. The Trans-Canada Highway (TCH), a major corridor in this region bisects Banff and Yoho National Parks (Clevenger et al., 2009). A range of mitigation measures like overpasses, underpasses and fencing were designed to reduce wildlife mortality and population connectivity. For twelve years, researchers, in the form of Banff Wildlife Crossings Project (BWCP), have closely monitored how different species use these structures, and in the process have collected a huge volume of valuable data on crossing frequency, species preference and behavior. Species like wolves, coyotes, cougars, lynx, black bears, grizzly bears, wolverine, deer, elk, bighorn sheep, and moose were detected using methods such as obtaining hair/DNA samples with the help of track pads, recording specific human activity wherever relevant, and by

using motion sensitive and remote infrared-operating cameras. Overall, within the monitoring period of twelve years, the researchers have found wildlife using the crossing structures more than 185,000 times. Some of the many specific results are: (i) The number of recorded grizzly bear crossings soared 35-fold, from five instances in 1996 to 177 in 2008 (as a proportion of all wildlife crossings, they went from one of every 2000 crossings to a little more than one in 100 crossings); (ii) elk usage declined by 45 percent as a proportion of all crossing, while deer usage increased significantly from 24 percent to over 70 percent just within a 10-year period; (iii) several unexpected species like red fox, striped skunk and hoary marmot have been detected using the structures while the boreal toads have been detected on the Wolverine overpass, garter snakes were seen Duthil wildlife underpass, and beavers were found using the Redearth Creek pass; and (iv) species such as moose, wolverine and lynx were found using wildlife crossings in North America for the first time, even though they were using Banff crossing structures less often than other large mammals (wolverines were detected using three different crossing structures four times, while lynx were found using two crossing structures twice). Elk mortality rate is found to be moving towards zero along the mitigated section of the freeway. Most importantly, clear decrease in the number of per capita mortality rates was recorded for elk and wolves using the Bow Valley overall (even though the significance varied across the three phases of constructing the crossing structures) improving motorist safety by reducing animal–vehicle collisions considerably. Also, with most human and wildlife activity located at the valley bottoms, having current, reliable and localized data on movements of carnivores helped wildlife managers improve local community and tourist safety along with wildlife safety. Banff Field Unit's human-wildlife conflict specialist uses updates from the BWCP to obtain real-time data on the movements, location and direction of travel of species or individual animals of human-wildlife management concern.

5. Re-installing habitat connectivity at the Donaghy's site has allowed many plants, vertebrates and invertebrates to colonize newly created niches and has also improved local community understanding of the value of defragmented landscapes (Tucker et al., 2009). From 1995 to 1998, restoration plantings were undertaken in north Queensland, Australia, to establish Donaghy's Habitat Linkage, a 1.2 km x 100 m planting of rain forest species along Toohey Creek. The project was designed to link two large habitat areas – Crater Lakes National Park and Wooronooran National Park – to provide passage for a fauna species potentially affected by isolation. These specifically included the Endangered Southern Cassowary and the locally endemic Musky-rat Kangaroo. This project was managed by Queensland Parks and Wildlife and involved substantial community participation with the help of other partner groups. It was decided ahead of the restoration work of the corridor that the project will be monitored. The monitoring program sought to observe and document any changes taking place within the linkage, and to determine whether these changes were beneficial within the context of local landscape. For the baseline monitoring, all native and exotic plants occurring within the area to be restored were identified to species level prior to the restoration works and the position of the individual trees and climbs were mapped. Survey showed a diverse set of species. Mammals surveys were undertaken at the beginning of the project to examine the potential effects of the restored corridor on small terrestrial animals using Elliot traps and cage traps to sample the pasture and riparian zone habitats that need to be replanted. A "Post-planting monitoring" section was designed by placing trapping grids at 200 m intervals along the strip. Inside the

proposed linkage area, baseline sampling indicated one rain forest mammal species – the Fawn-footed Melomys – present at the onset. Other surveys were also carried out so that small mammal fauna was recorded. After the completion of the planted corridor, three transects where established in each block to conduct vegetation surveys twice yearly for three years. Seedling density per square meter was calculated to provide an overall measure of seedling density, in each year's planting. On the other hand, the small mammal and reptile and invertebrate trapping began immediately after the linkage was completed in 1998 and continued till 2000. Five trapping grids were established in the linkage, in the forests at either end and in the pasture adjacent to the linkage. The two pasture grids were established to ascertain whether any rain forest mammals utilized this habitat. All mammal captures were identified, weights, sexted, assessed for breeding conditions, ear-tagged with a numeric tag and released immediately after. A total of 4472 native seedlings were found to have regenerated naturally within transects during the three years of the study. These represented 48 families, 99 genera and 119 species. Of the 119 species regenerating in the corridor, 35 were known not to have been planted or to occur prior to the project commencing. Therefore, they were assumed to have been dispersed from the forests at either end of the linkage. The 10 most common species accounted for 60% of the total seedling pool. Around 20% of species recruited were represented by only one individual and 47% were represented by less than five individuals. Given that the sampled area represented less than 2% of the total area restored, there appears to have been a very large number of seeds that have been dispersed into the plantings. On the other hand, a total of 46 fauna species were recorded during the study period. Twelve species of mammals were trapped over the 3-year period, within the 11 trapping grids. The Bush Rat and the Cape York Rat were relatively common, although numbers trapped fluctuated markedly over the course of the study. The Fawn-footed Melomys was the most frequently trapped small mammal (46% of total captures) and the only rain forest species captured in the linkage area prior to restoration works, but now rapidly moving into the restored area with population densities increasing considerably before stabilizing. The endangered Musky-rat Kangaroo was detected four times. The reptile and invertebrate trappings were not significant in number. Aside from the ecological benefits, the project also resulted in broader social outcomes, having stimulated significant interest and increased awareness of the broader ecological connectivity issue in the local community. It has significantly improved local understanding of the biological outcomes and benefits of ecological connectivity at a range of scales. In 2001, the Donaghy's Corridor Nature Refuge was declared, officially placing the linkage area under the community's responsibility. The Donaghy family were instrumental in this process, emphasizing the importance of engaging with landholders in a meaningful way and ensuring landholder contributions and needs are considered.

6. A qualitative analysis of the Monte Pascoal–Pau Brazil Ecological Corridor Project (MPPBECP) reveals positive environmental, economic, and social benefits. Established in 2004, the goal of the MPPBECP was to reforest 4000 Hectares of rainforest and protect 20,000 Hectares of rainforest (Paiva et al. 2014). The initiative built corridors between two national parks, thereby increasing economic and social activity. Trading carbon credits with firms will help finance the project. By interviewing the inhabitants in the corridor's proximity, the study confirmed that the MPPBECP was achieving environmental objectives based on positive responses on topics such as: climate change mitigation, reforestation, and increased presence of bird and animal life. Economic benefits were established based on positive responses on topics such as: soil erosion,

water quality, and general crop health.

7. Madagascar is world-renowned for its unique biodiversity of not just animals but also its endemic plants. Ensuring the survival of these species is complicated by the poorly regulated use of the country's natural resources (Manjaribe et al., 2013). More than 80% of Madagascar reported to have been living under extreme poverty as of 2010, and 90% of people living in extreme poverty depended on forest resources as a direct means of support. Therefore, it became extremely necessary for reforestation and habitat connection projects to take place. A pilot project was conceived to expand habitat and reconnect forest fragments in Kianjavato Commune in southeast Madagascar. This restored corridor combined native diversity with rapidly growing introduced and native pioneer trees, following a three-tiered corridor design that capitalized on the region's mountainous terrain. The process of seed selection, transplantation, and survival rate of seedlings over a 16-month period were recorded. Particularly, the uppermost 50% of each mountain was planted with 38 woody species and other close approximates of the native forest. The tier was divided into two categories, pioneer and secondary species. Most of the pioneer species were not native, but results showed that four specific fast-growing resilient native species could be suitable alternatives. More than 70,000 seeds of secondary species were sourced from fecal samples from the wild free-ranging black and while ruffed lemurs. As a result, the seeds that went through gut passages were found to germinate significantly better. Commercially valuable trees, belonging to the community member, were designed to be grown on the lower half of the mountain ranges, mutually benefiting the forest landscape and the community. The success of the pilot project was mainly evaluated based on the survival rates of the flora planted. The first evaluation was performed in June 2010 and focused on survival or pioneer seedlings. The second evaluation was carried out exactly a year later and included all species. The proportion of seedings that survived six to 16 months varied across variable such as site, category and species. The pioneer *Albizia saman* had the highest survival rate of Permanent Tier seedlings at 97.5%, followed by *Harungana madagascariensis* at 94.7% and *Albizia chinensis* at 87.4%, one year after being planted into the reforestation corridor. *Albizia lebbeck* had the lowest potential to survive out of the pioneer species due to predation by herbivores. *Albizia chinensis* was found to have the highest relative growth rate in height and stem diameter with some individuals producing flowers and fruits after one year. Survival rates varied widely for secondary species. Poor performance was noted in *Tina apiculata*, the two *Chrysophyllum* species. The death of the majority of seedlings for all of the aforementioned species occurred mostly at a site where survival rates ranged from 5.7 to 23%. However, rates improved when these seedlings were planted near the edge of the existing forest in *savoka* (53–80%). More than 13 native species had high survival rates of 80 to 100%, demonstrating a tolerance for harsher environmental conditions. The timber species *Khaya madagascariensis* (87.2%), *Cryptocarya dealbata* (85.4%), and *Suregada celastroides* (81.8%) had the highest seedling survival from nursery to corridor in this tier. Eight species were selected for the Non-Timber Tier. The survival rates of *Tamarindus indica* and *Persea americana* trees were 100% during the evaluation period, although only a small number was planted. The survival rate of *Cinnamomum camphora* seedlings in the reforestation corridor was also high at 97%. The species that had the lowest survival rates were between 49% and 60%. Both species of *Annona* had similar seedling survival rates (75.7– 77.4%), which were close to that of *Anacardium occidentale* at 80.0%. *Moringa oleifera,* known for its medicinal properties and high

protein foliage as well as its water-clearing characteristics, had the highest growth rate amongst Non-Timber Tier. This highlights the promising landscape of the corridor with a potential to restore ecological services for the benefit the communities. Although, the conversion of forest to agricultural lands might provide greater access to food logically, there is no mechanism in Kianjavato or Madagascar to replace the ecological services provided by the razed forests. Throughout the project the local community was seen to be a willing participant starting with 58 people attending the first reforestation village meeting. Furthermore, participants were able to sustainably harvest from the lower 50% of the reforested land that represented the Timber and the non-Timber Tiers. Approximately 3,400 seedlings were estimated to have been voluntarily planted by community members on three separate occasions in 2010 while the corridor was being planted.

8. The road and railway network in Poland were built before its society became environmental conscious (Brodziewska, 2005). Therefore, several roads go through sensitive areas that include national parks and wildlife reserves. After Poland joined the EU, it became a requirement to improve the environmental legislation. This made the monitoring, before and after the building of such constructions, necessary along with the preparation of environmental assessment studies. Other than the political and environmental implications, Poland was also susceptible to societal issues that came with the construction of such roads on forested land. As roads became national and international highways, traffic increased along with driving speeds; and as a consequence, the risk of collisions increased drastically. Many motorists died in fatal accidents. On an average, a 160 km highway would see 40 accidents with mammals on monthly basis in 2003. As a result, consciousness of the society grew enormously, and it pushed for an institutional action. After identifying animal (small and large mammals) migration routes, building of passages and bridges for wildlife became a necessity. As a result, ten overpasses and one underpass were built. They are all located along the E65 international road. The decision on the exact locations of these corridors were made after detailed interviews with national park officials and foresters, and also results of field work. As a result, the follow-up monitoring of these structures showed that the tunnels very extremely effective with nearly 100% of all the amphibian and reptile species and 85% of all the small mammals species estimated to be using the corridors.

9. An assessment of canopy bridges installed to facilitate monkey movement across forests in Brazil reveals that the bridges are having their intended effect of facilitating monkeys' and other species' safe passage between forest canopies (Teixeira, 2013). The Urban Monkeys Project, a conservation group, undertook the installation and study of six canopy bridges installed in areas where howler monkeys and other species risked death by using power lines to traverse forest canopies. Using camera trap data and enlisting locals to document sightings, the study revealed that four of the six bridges provided evidence of movement of howler monkeys, opossums, and porcupine. The study classified the six areas as arboreal, urban, open vegetation, and water. The areas that recorded the most activity had the least urban cover, while the areas that recorded no activity were dominated by urban cover. While the study did not evaluate any reduced deaths from power lines, the results are encouraging that such man-made corridors could facilitate safe wildlife passage and engage the local community in an educational experience of their local flora and fauna.

10. An assessment of canopy bridges installed above highways and roads to facilitate wildlife movement across habitats in Queensland, Australia reveals positive evidence of canopy use by wildlife (Weston et al., 2011). The Wet Tropics area of Queensland is known for animal diversity. Specifically, the habitat hosts five endemic species of possums, four of which are classified as rare. Three of these ringtail possums and Lumholtz's tree Kangaroos are considered canopy dwellers and thus highways and roads can act as complete barriers to movement thereby leading to the risk of subpopulation isolation. The team installed four different types of canopy bridges, tunnel, single rope, wide, and narrow at four different locations, with multiple bridge types at each location to determine if the animals had any significant preferences. The team determined bridge type by location based on topography, distance, and other factors. The team determined the locations based on forest canopy on either side of the road, vehicle traffic, and other factors. All locations were selected based on established presence of the target species. The team employed direct sightings, scat analysis, camera traps, and hair analysis to establish use. The team captured evidence of nine distinct species including the rare species across the four locations with varying monitoring methods across the different bridge types. The team observed no roadkill in the vicinity of the bridges over the course of the study but recommends a more structured before and after roadkill survey to determine any impact from the bridges. The study elicited public support and interested and provided to be an educational tool for the community. The study offered encouragement that relatively inexpensive and hardy bridges could offer safe passage for rare arboreal mammals to access other habitats and subpopulations.

Conclusions and Recommendations

All the studies above focus on benefits of constructed and restored corridors, and each of them note positive effects of the corridors not only on the environment but also on the key communities at stake. In all the studies the community is noted to have benefited from the construction of corridors. While the three Terai Arc Landscape studies focus on mitigation of human-wildlife conflict, two studies talk about enhancing highway safety and mitigating road-kills. The study based in Madagascar talks in depth about community benefits from gaining basic needs from the ecosystems restored. It also indicates the importance of flora as much as fauna while restoring corridors. All other studies talk about enhanced environmental awareness and communities' willingness to participate as they realize their benefits from corridor constructions and management. In two studies, communities are even handed over the projects and take ownership. Overall, we do see that strategic and well-planned corridors bring community benefits such as better harmony with nature, ecosystem services, social capital, sustainable lifestyles, safety, security and social and environmental awareness. However, as some of the above studies note, there is scope for better management of communities during restorative or any environmental initiatives. Often, communities are given temporary incentives to help the advancement of projects in the short run. However, these incentives are not sustainable, and the communities' usually relapse into their old habits and lifestyles. Therefore, it is important to monitor and help communities sustain the transformation that took place post building of such structures.

Supporting Studies

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