



LANDSCAPE CONNECTIVITY SCIENCE AND PRACTICE:

WAYS FORWARD FOR LARGE RANGING SPECIES
AND THEIR LANDSCAPES



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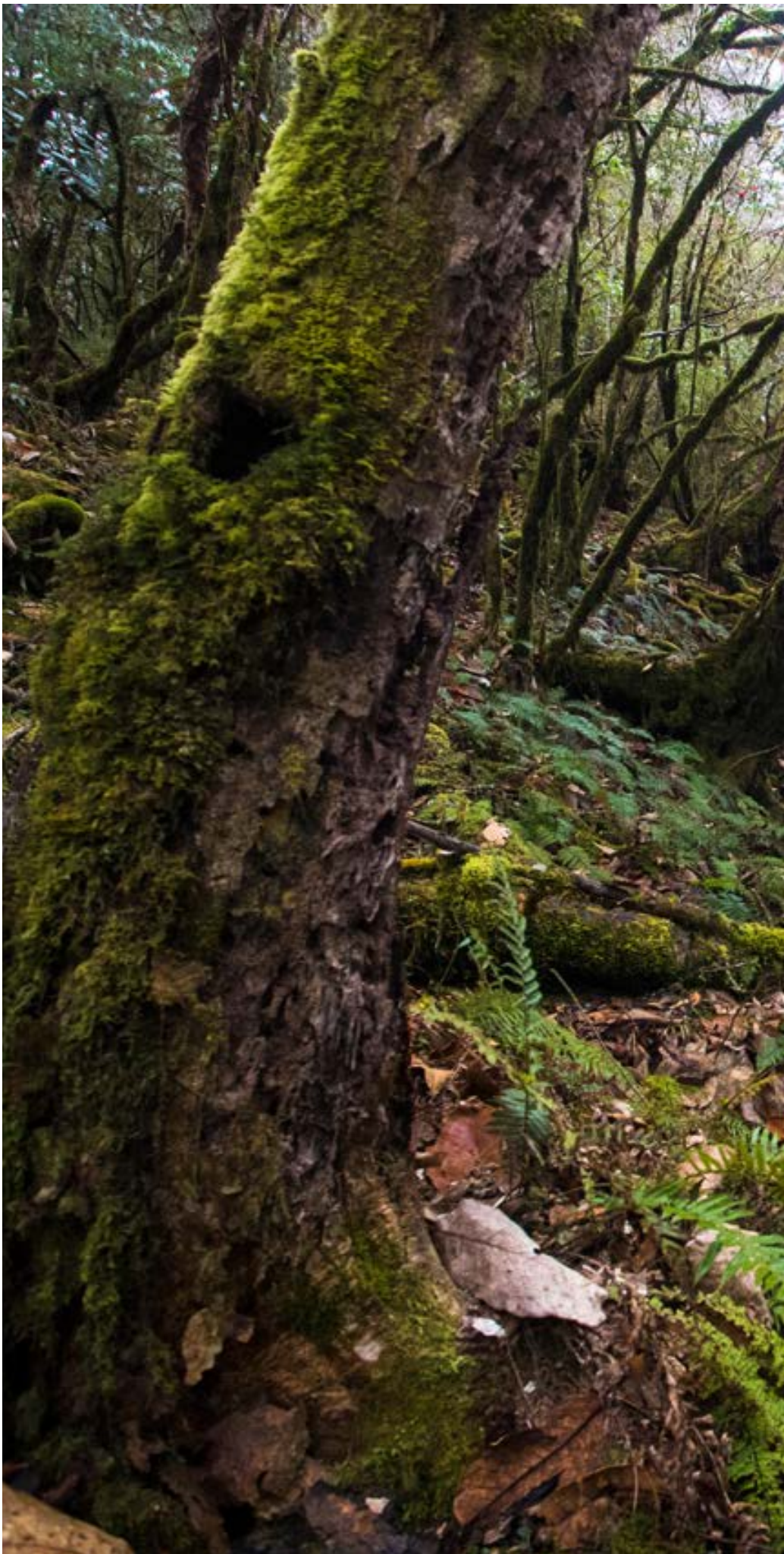
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CONTENTS

1. BACKGROUND AND OVERVIEW	6
2. DESIGNING FOR CONNECTIVITY	10
3. MONITORING AND THRESHOLDS OF CONNECTIVITY	13
4. ENGAGEMENT STRATEGIES FOR CONNECTIVITY	16
5. CONNECTIVITY POLICY, REGULATION AND GUIDANCE	19
6. INSIGHTS FROM LONG TERM CORRIDOR PROGRAMS	23
7. EMERGING FIELDS IN CONSERVATION CONNECTIVITY	26
8. ANNEX 1: LANDSCAPE CONNECTIVITY WORKSHOP AND PARTICIPANTS' LIST	29
9. ANNEX 2: GLOBAL CORRIDORS CASE STUDIES	31
10. REFERENCES	31

EXECUTIVE SUMMARY

The gathering of experts and practitioners in the large wildlife, landscapes and connectivity fields in Delhi in 2018 was a valuable process to build knowledge and lessons on current practice, gaps, and innovations around connectivity science. The overarching message that emerged was that for connectivity to function in practice it requires some fundamental shifts away from current thinking and approaches: we need a conceptual shift away from linear corridors to seeing landscapes through a permeability lens; we need to enhance monitoring and develop thresholds for connectivity; we need to move away from management of corridors to engagement strategies with communities; we need regulatory frameworks for connectivity; and we need corridor planning and functioning across the board to be underpinned by principles that bind wildlife movement needs with development agendas and future needs of people. These major recommendations and actions to contribute toward them are detail here.

Designing for connectivity

Move away from linear corridors toward landscape connectivity and permeability. ACTIONS required:

- Develop landcover permeability / resistance layer analysis for target species;
- Connectivity design should be based on biological consideration, spatial usage, and community considerations. Develop a two-tiered system of delineating corridors that encompass existing and potential matrices of land-use or habitat and focal connectivity areas;
- Develop standardized multi-species methodologies for connectivity to inform spatial planning; and
- Develop and pilot methods to delineate connectivity space in a manner that allows integration into development planning.

Monitoring and thresholds of connectivity

Enhance connectivity monitoring and develop thresholds such that we can identify tipping points of loss. ACTIONS required:

- Develop thresholds for functional connectivity for target species;
- Explore emerging metrics to monitor permeability (e.g. land cover change);
- Enhance on-ground monitoring frameworks of wildlife movement and land-use change through improved scientific monitoring and community participation, and ensure processes are simple, robust, peer reviewed, and periodic; and
- Enhanced monitoring should be designed to inform planning, improve functionality, minimize conflict, and allow greater prospect of sustainable development and avoided extinction.

Engagement strategies for connectivity

Move away from passive corridor management plans toward proactive engagement strategies with stakeholders who use that space. ACTIONS required:

- Develop and pilot engagement strategies in known and existing connectivity areas (the 'matrix') of landscapes;
- Engagement strategies need to factor in sustainable financing for actions, must be climate resilient, and act as a coordinating tool for stakeholders locally and at higher broader levels; and
- Incorporate land-use management into engagement strategies to improve connectivity potential in non-habitat areas as well.

Connectivity policy and regulation

Shift the locus of influence from passive civil society / government / scientific guidance, to regulated control and management of connectivity. ACTIONS required:

- Explore and introduce the notion of 'no net loss' of connectivity in landscapes. Here the onus of connectivity is transferred to the developer or sub-national governments and those undertaking land use change (This shift is akin to pollution prevention); and
- Connectivity spaces must be formally or legally designated with clear protocols for monitoring. This will be enhanced by improved land-use classifications and delineation of corridor complexes / mosaics.

Connectivity principles to underpin design, planning and implementation.

Move away from ecologically-exclusive wildlife passageways, to connectivity matrices that factor-in change from development scenarios and climate shifts: ACTION required:

- Develop national level guiding principles for connectivity that reflect compromise to local aspirations and economic development plans.





1. BACKGROUND AND OVERVIEW

Wild tigers occupy around 7% of their historic range and occupy less than 40% of the habitat they did in the 1990s (Dinerstein et al. 2006). Remaining tiger populations inhabit increasingly fragmented and isolated patches of land in an expanding human-dominated landscape. The international response through the Global Tiger Recovery Program reflects the urgency and ecological scale of the conservation challenge through focusing support to these priority areas through a landscape-based approach. Protecting and restoring the ecological integrity of these landscapes is considered the last line of defense against tiger extinction in the wild (WWF-TAI 2013). These landscapes also support some of the most vulnerable and marginalized human populations as well as critical ecosystem functions. At the same time, pressures on these areas are also immense and include hydro-power development; road and rail expansion; logging and extractive industries; and an expanding agricultural estates (GTI 2012). As a landscape species requiring large and diverse habitats, rich in prey and with minimal human disturbance, the challenges to the long-term survival of tiger are clear.

1.1 The need for a tiger corridors strategy

One of the key pillars of the Tigers Alive Initiative is to develop a set of tools that help to understand landscape connectivity, identify and protect critical corridors, and monitor their functionality. Tiger corridors are recognized as vital to a long-term landscape strategy but are also the most fragile components exposed to acute and chronic threats. If movement corridors are lost, landscapes become fragmented, species dispersal becomes limited or ceases, and ecological systems can begin to break down. In the case of tigers, they become isolated in smaller populations, increasingly exposed to hunters, their population densities can initially rise in a confined area, but then can be affected due to fighting and inbreeding. Increasing human-tiger interactions can also be attributed to fragmentation and loss of corridors.

Maintaining landscape connectivity through corridors is therefore vital for tiger recovery and for maintaining local support for tiger conservation. Various WWF landscape teams and national offices work to assess and identify where corridors are, lobby governments to protect them, and develop action plans to maintain them. Many other organizations and governments are also working towards this aim. However, a coordinated and strategic approach to maintaining tiger corridors has yet to be developed. WWF Tigers Alive strives to institutionalize best practice – through using existing landscape expertise to support other landscapes – and it is through this approach of pooling knowledge via a technical workshop and a subsequent strategy development that we seek to continue in this vein.

New approaches to corridor identification, monitoring and protection are emerging globally as technological advances and the sharing economy progress rapidly. Commensurate with this progress, practitioners, governments and decision-makers are evolving the science of maintaining and restoring corridors through integration with markets, online economies, financial flows, with policy levers, and citizen science and smart phones. This report shines a light on some of these innovations and explores their potential in tiger recovery.

1.2 Expert insights

Sejal Worah, WWF India: the changing face of connectivity science.

We have been working on corridors for two decades, and the more we understand about their design and how they function, the more questions emerge. For many years we have conceptualized corridors as linear, mostly forested patches that connect two larger spaces that wildlife somehow find. Since then, we've learned that corridors are likely to be a mosaic, perhaps even peri-urban spaces that we didn't think wildlife would use. Corridors are under great stress and experiencing increasing threats to their maintenance. Yet while our understanding of corridors becomes more nuanced and sophisticated, the solutions proposed are often based in the past. How do we really protect corridors? Do we know what functional corridors are? Do we know that if, when restored, wildlife will use corridors? Do corridors lead wildlife from a 'good' habitat to 'bad' ones? Do we really have consensus on why we need corridors? We used to focus on genetic diversity and dispersal. But we also need to reimagine corridors that maintain land use and connected spaces or permeability. Now is the time to reflect on our current work, adapt our model, and catalyze a new connectivity narrative.

Soumitra Dasgupta, Inspector General of Forests, Ministry of Environment, Forests and Climate Change: balancing connectivity and development.

In India we have high level recognition of the need to maintain protected areas and connectivity conservation not only for the benefit of wildlife, but also to foster co-existence. India has some 769 protected areas, plus eco-sensitive zones protecting other land, yet in parallel we must push to improve the public interest aspects of our development – the railways, gas connections, access to water, roads, and social connectivity. And herein lies the immense challenge: how to get that balance right between people's needs without impinging on the behavior and movement of many of our iconic species.

There have been various challenges. The Wildlife Protection Act is in place, but it lacks the muscle to protect corridors. And in other places the success of species recovery has far outpaced the development of solutions to address confounding factors. For instance, in West Bengal in Midnapore, elephant corridors have been functional for three decades due to solid forest protection. From around 30 individuals, the population is now 20 times higher and requires 20 times more space. How do we deal with such emergent landscape pressures?

Recent developments across government are however leading us in the right direction. In October 2017 the National Wildlife Action Plan was enacted. Critically it describes how to secure corridors. We are also looking at ways to develop mitigation measures, and the Wildlife Institute of India has developed guidelines for structural mitigation measures for linear infrastructure to minimize harm to wildlife. We are also looking at ways to move out of isolated protected areas-based plans, to more integrated management plans for sanctuaries and national parks that are landscape-based.

Rajesh Gopal, Secretary General, Global Tiger Forum

Tigers, and other large ranging species, pose very clear and present challenges to our current land use policies and practice. Even where land use policies and spatial plans are in place it is very difficult to implement them as the economic growth paradigm is of such importance nationally and regionally. Put simply, tiger range countries cannot afford to say no to intensive, land-extensive development.

In the Indian context, tiger lands – a core for reproductive surplus plus a peripheral buffer zone – are legally recognized under the Wildlife Protection Act. Within the core areas there is a tiger-centric approach, while in the buffer there is a co-occurrence agenda. And it is often these buffer zones, and the lands that link the buffers that throw up many challenges.

What we think / designate as corridors between core areas, may not actually function that way. Tigers are moving across other lands, along dry riverbeds, through plantations and agricultural fields. They move through vast human spaces that cannot be designated tiger lands or managed as conservation land. While the public are happy for the core areas to be supported for conservation, if we start looking at a conservation agenda outside core zones we are met quickly with opposition.

Corridor management therefore requires a whole suite of new approaches – it requires an engagement portfolio to work with the stakeholders in those areas. These stakeholders are primarily the communities, followed by the government agencies and commodities sectors, and finally the tertiary stakeholders – the towns and urban populations. Each landscape will differ, but a process to engage stakeholders across landscape matrices for mutual benefit will be critical for landscape connectivity.

Any engagement strategy needs to consider three socio-economic features: what changes have occurred in the landscape up till now; what is the rate of change; and what will happen moving forward? And in parallel, we need to overlay the biological knowledge: when / where animals move; where do they go? where do they stay? And where do they breed?

SP Yadav, Chief Conservator of Forests, Uttar Pradesh Forest Department.

The loss of tigers from Sariska Tiger Reserve in 2005 is a demonstration of the need for work to secure tiger corridors. While poaching was an acute issue, the compounding factor was the lack of connectivity and corridors – the tiger population simply could not be supplemented by other populations.

We generally have a good understanding of macro level corridors but lack in-depth knowledge of micro scale movements and corridors. The coarseness of our current knowledge is then exposed when development applications come across our desks. There is a lot of pressure to develop corridors, and certainly to allow for mining or infrastructure development, and our understanding of movement corridors precludes nuanced and science-based input into such processes to seek maintenance of connectivity.

There is a critical need to raise awareness of the importance of corridors and connectivity with the public and government agencies, and we need to begin to consider the legal protection of designated corridors.

Prashant Verma, DIG (Forest), National Tiger Conservation Authority (NTCA).

The two key issues for corridors and connectivity are: that corridors should be considered as part of infrastructure planning; and that monitoring needs to be a fundamental part of any mitigation option enacted.

Without any legal protections, corridors and wildlife connectivity are a blind spot in development planning and construction. There have been calls in India for no approvals to be given to any proposed development that will directly impact wildlife (at least not without dramatic mitigation measures). There have even been proposals for “Animal Passage Plans” to be incorporated into every linear infrastructure project.

Various developments have included such mitigation measures, however there has been a subsequent lack of monitoring and performance measurement of those measures. Not only to determine if wildlife use them, but also if they are being constructed according to the plans and guidelines.

Ashley Brooks, WWF Tigers Alive: a crowded world for large-ranging species.

Within the area encompassed by a five-hour flight in any direction from Yangon, Myanmar, most of the world's population reside. i.e. more people live within that area than outside it. Around half of global infrastructure investment occurred within this area in 2017, and by 2050 3.3 billion people will live in urban areas there, and incomes and consumption will match those of Europe today. Similarly, all the Asian rhinos, wild tigers, orangutans, Asian elephants, giant pandas, and snow leopards live in that same area. The competition for space is already fierce. Arable land is as low as 499 m² and 626 m² in Bangladesh and Malaysia respectively (far smaller than an Olympic sized swimming pool at 1,250 m²). Habitat loss since 2000 across tiger landscapes has varied from 3-14%, with Sumatra losing one cricket field sized area of forest every hour, seven days a week, from 2000 to 2015. Compounding the loss of habitat is the rapid pace of infrastructure expansion with highways, railways, pipelines, freeways, canals, and fences becoming a serious threat to landscape connectivity and meta-populations overall. Evidence from some tiger landscapes is already showing that even if tiger poaching is stopped, the loss of habitat and connectivity is the critical issue going forward re tiger persistence. The challenge now is to re-examine ways we align our conservation connectivity goals with the development agendas of countries, and how do we better engage with communities and stakeholders more effectively?

Report structure and key:

This report is a narrative compilation of a technical workshop. The workshop itself was a combination of presentations, chaired plenary discussions, and technical group discussions. Throughout the report:

- Presentations are titled as “Case studies”
- Chaired plenary discussions have RED section headings (e.g. [2.2 Defining connectivity](#))
- Key comments, inputs and quotes during plenary discussions attributed to the relevant expert capitalized in-text (e.g. MALLA), and full names listed in Appendix 1.
- Technical group discussions have GREEN section headings (e.g. [3.2 Tools and technology for connectivity monitoring](#)).



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2. DESIGNING FOR CONNECTIVITY

Do we know where movements corridors really are? How do we determine and design them? Who was involved - communities / government in the process? What scale is most appropriate to work at and what is feasible? What are the costs of corridor identification?

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2.1 Corridor design case studies

Learning from the collared tiger ‘Chandu’, Pranav Chanchani, WWF India

Captured in Pilibhit farmland and translocated to Dhudwa, Chandu’s movement up into the Churia Hills of Nepal provide many lessons. Re. design: Chandu’s movements did not follow what we had ascribed and predicted as ‘corridors’; the permeability of farmlands was underestimated; many of the movement corridors were in fact habitats; and corridor boundaries were exposed as very porous. This transboundary context also highlighted how previous studies had been limited by national boundaries rather than eco-geography and revealed that corridor restoration should not just be undertaken in bottlenecks alone. Re. monitoring: good tracking and data enabled good understanding of how much time the tiger spent outside designated corridors and protected areas but raised questions about how and what we monitor in other corridors and what we define as a functional or a secure corridor. Re. implementation: there needs to be much more information / data on tigers in corridors; more recognition of corridors and their impacts on distribution, abundance and conflict; and there must be clearer actions for effective protection in corridors and ‘sink’ – areas with high human use. Re. policy: there is a dearth of policy to designate / protect corridors on private lands, to mitigate infrastructure impacts, or for transboundary cooperation on corridors.

The juxtaposition of conflict mitigation and connectivity for conflict-prone species in India, Divya Yasudev, Wildlife Conservation Society India

Connectivity is lost on public and private lands, and we need to build up better knowledge of what are the factors that limit animal movement. For elephants we need very nuanced understanding as not all elephants are a threat. There are no perfect methods to designing areas of connectivity conservation, and we have to continue to test and pilot approaches, and we must factor in dynamic design as context is always changing. The challenge for connectivity design is how do we factor in dynamism into policy frameworks?

Identifying Malay peninsula corridors - what does it take time, effort and resource-wise? Mark Rayan, WWF Malaysia

Work to identify wildlife movement corridors in Malaysia was an integral part of the national Central Forest Spine Strategy and linked with infrastructure planning. The critical gap at the start of the planning process was that there was a lack of knowledge about how and why wildlife moved in certain patterns, and where and when specifically, they were moving across the primary linkage areas of the central forest spine. WWF Malaysia was able to lead the design and research into some key sites to fill these gaps. One site at Belum-Temangor provides useful details as to the effort required to obtain enough data: Study site: 156 km² of sampled area (156 1x1 km sub-cells); Sign surveys (5 months); Sightings, tracks, scats, claw marks; Survey >1 km for each 1 km² sub-cell (x3); Sign survey effort = 651 km walked. Camera-trapping (3 months); 2 camera-traps in each 4 km² cell; 78 camera-traps; Checked monthly; Camera-trapping effort = 6,434 trap-nights. Findings: presence of species: tiger (34%), elephant (67%), gaur (48%), tapir (42%), and sambar (39%).

Other findings: breeding evidence of tiger, elephant, gaur, sambar deer and other mammals; detected nine adult tigers and eight offspring; three adult tigers detected on both sides of the highway. Budget based on three teams doing surveys over 26 man-days: USD 53,000. The inter-relationship between wildlife movements and habitat suitability reflects the assumption that animals choose travel routes in a similar way to choosing habitat. The higher the intensity of habitat use, the more likely animals are assumed to use and move between these patches. Methodology and findings submitted to government planning agencies and used as the methodology and baseline for post construction monitoring of wildlife movements, as well as to inform design that maintains connectivity.

2.2 Defining connectivity

Connectivity means different things to different people. Often, the term is used interchangeably with corridors, though this is an ambiguous term. This leads to challenges when trying to frame a legal policy, especially at a global level, that promotes conservation across nations. There is a need to have a clear and standard definition of connectivity, and to delineate differences between terms such as connectivity, ecological corridors, rehabilitation etc. Perhaps, ecological outcomes of these interventions can clarify the differences among terms (REULING). This is reflected in many tiger countries where government officials refer to and talk about corridors outside protected areas in multiple ways (WORA). The IUCN is currently facilitating a definition for what a corridor and connectivity is. Key considerations are: how to come-up with something at the international policy level that is helpful to those on the ground; what is a well-defined, legally defensible definition for an area of connectivity; and how to ensure complex multiple use landscapes are factored in? (REULING). Challenges can emerge at the policy level in countries that will need to enshrine any definition of corridors into policy. In some cases, this may involve amending protected area laws / designations to add in new categories, and it will also require new training for forest / wildlife officials to ensure appropriate and agreed methods are used to identify and designate corridors beyond existing approaches (PARIWAKAM).

2.3 Data and knowledge of wildlife movement and behavior: when is enough and what is the purpose?

Knowledge on movement and behavior of wildlife is patchy at best, though it is a field that is rapidly improving. A single tracked animal can yield significant data on movement behavior and how it uses different habitat types (MALLA), but significant knowledge gaps are inevitable. More statistical modelling, more collaring, more research and variables can be added – but are these effective, what is needed and what is the ultimate purpose? More data and evidence are always better, as this is a key gap for decision-makers regarding corridors. However, statistical modeling has not used animal movement data well, and models perform better in non-novel, non-changing landscapes. I.e. modelling does not pick-up nor answer the complexities in such a dynamic system (YASUDEV). Other significant gaps are those tertiary data-linked areas. For instance, there needs to be a greater understanding of the interface between communities and wildlife before more advanced modelling or state-of-the-art technologies are used (CHANCHANI), and in cases where there are no political processes, then even the most basic datasets will be useless. Data capture and research will be ongoing, but ultimately the information needs to be sufficient to build a solid scientific evidence base for decision-makers to agree and establish corridors between protected area (GROVER), to build community knowledge and partnerships for ownership of wildlife passage and habitat use (CHANCHANI, MALLA).

“The question is not to capture all complexity but sufficient to make an informed conservation decision”

**Divya Yasudev
(Wildlife Conservation Society, India)**



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3. MONITORING AND THRESHOLDS OF CONNECTIVITY

Do we know where movements corridors really are? How do we determine and design them? Who was involved - communities / government in the process? What scale is most appropriate to work at and what is feasible? What are the costs of corridor identification?

3.1 Corridor monitoring case studies

Corridor and conflict monitoring: what it tells us about the corridor. Jyotirmoy Jena, WWF India

The case study focused on identification and monitoring of wildlife corridors in Satpuda Maikal Landscape of central India. Several methods such as occupancy survey, opportunistic camera trapping, monitoring of cattle kills by large carnivores and GIS were used to identify functional corridors. Regular monitoring led to comprehensive understanding of corridor functionality, tiger habitat blocks, and critical linkages. The monitoring also led to better understanding of the drivers affecting the corridor habitats. Better corridor knowledge has now led to corridor management plans and evidence to government for enhanced management. An added outcome of the corridor monitoring and use of conflict information (i.e. livestock kills by tigers) was that it provided substantive socio-ecological information and contributed to map conflict hotspot mapping and conflict management activities.

Connectivity, genetics and futures. Uma Ramakrishnan National Center for Biological Sciences, Bangalore India

Critical to continued recovery is the ability for tigers to move between landscapes. Monitoring such movement is challenging as dispersal events tend to be rare. Thus far, camera-trap based individual identification has been the main tool for monitoring individuals in the wild. However, another tool is fast emerging as an a powerful and additional (or alternative) option. Non-invasively collected genetic data can be used to investigate connectivity between landscapes in many species. The tiger genome is 2,400 million bps long, and each tiger has a unique genome. The ability to read a portion of each individuals' genome allows us to distinguish between, and track individuals. More recently, new methodological developments in the ability to read DNA have enhanced our speed and decreased costs. We recently proposed a method, MPCRseq, that types an alternate marker in tiger genomes, Single Nucleotide Polymorphisms or SNP. In summary, these novel methods (see Figure 1 for schematic of methods <https://www.biorxiv.org/content/early/2018/06/20/349472>) allow us to generate data for 100s of SNPs quickly and accurately from very poor quality samples. The rough cost of genotyping a tiger is \$8 (when analyzing up to 250 samples together, costs may increase with fewer samples), and time taken from sample to data is around 7-10 days. A critical added value will be that country participation will allow generation of a range-wide geo-genetic map that can serve as a baseline for connectivity across tiger range. We propose a range-wide initiative to identify and track individuals across tiger range countries using these common, easy to use (relatively), cheap and accurate methods.

Using elephant movement data to enrich understanding of corridor use in the Western Ghats Nilgiris Landscape India. Boominathan, WWF India

Using direct sightings, transects, local interviews, camera trapping as well as movement data from collars, WWF India has been able to build up a substantive body of knowledge about the movements and habitat use of a population in

the Western Ghats Nilgiris landscape. Complemented with other monitoring methods, the movement data has been key to building comprehensive evidence for elephant corridors. There are five main elephant populations linked largely by two corridors. The data has given a clear picture of: the seasonal variation in range and foraging areas; clan and specific male movements; which parts of corridors individuals prefer and when; the size of the area served by a corridor; whether individuals feel safe crossing corridors (day or night); and captured rare / uncommon movements across corridors (e.g. specific corridor use by males only in musth). Ultimately the knowledge helps to build a more nuanced understanding of threats to corridors and demonstrate the relative impacts if specific corridors are lost. For instance, better movement data helps to determine the role of habitats and corridors to overall population genetic connectivity, or for specific individuals' survival.

National level monitoring of connectivity in India. Qamar Qureshi Wildlife Institute of India

Monitoring of corridors for connectivity at large scale offers up various challenges. First it has to be species specific and must take account of tertiary issues at large scale such as linear infrastructure and noise pollution. Second at large scales, isolation, genetic drift, and genetic mixing / pollution become issues, and any resultant sub-species must be factored in. Data collected during monitoring should be shared across connectivity consortia to broaden the application of it into the future.

3.2 Tools and technology for connectivity monitoring

Discussion of methodologies for monitoring connectivity start with a list of existing and emerging tools and technology to gather data that make efforts easier and time faster. Invariably however, 'how' the tools and data are used as well as the more linked processes also become central to the proposed ideas and are considered key gaps to current connectivity programs.

Technology and specific tools for monitoring:

GIS	Collaring
Genetics	Pressure pads and SMS sensors
App-based technology	i-naturalist
Smart phone / patrolling	Thermal cameras
Electronic eyes	Climate & scenario modelling
Block chain to trace commodities	Global Forest Watch
Rapid Response Teams to monitor	SMART
Drones	Statistical models

Various linked processes were also identified as critical to effective monitoring and essential for adequate use of technological tools. These included: balancing technology with social science and active community participation in monitoring land use and habitat change; joint development of databases, monitoring processes, and the co-development of knowledge and submission to government with communities; more training for effective lobbying of decision makers; partnerships with scientific institutes; citizen science and use of public and school children to help monitor and collect data (e.g. on wildlife vehicle collision); inclusion of more social indicators in monitoring frameworks; land purchase; enhanced legal and / or administrative tools to designate a focal body to collect and integrate data / info from various stakeholders; and the development of systems for better and more accessible data dissemination.

3.3 How to make monitoring count

Monitoring should not take place for the sake of it, there needs to be a focus on the end-use. Monitoring itself needs to involve participation of communities and government agencies. Reporting needs to be done for the purpose of educating the communities, public and government, but in some cases, it may be more appropriate to specifically support communities to report upwards. Reporting can also be used to lobby governments or incentivize communities to maintain permeable landscapes for wildlife movement. Reporting needs to be speedy, simple, regular, accessible and timely – and particularly during policy development processes.

“Thresholds and tipping points of connectivity must be determined. In cases of imminent species loss, knowing thresholds will allow for tactical and urgent action plans to be activated when a threshold is about to be breached”

**Melly Rueling
(IUCN Connectivity Conservation Specialist Group)**

3.4 Long term monitoring

Long term monitoring is essential – particularly to transcend and inform policy cycles – but the long-term conservation objectives must be defined before planning and initiating it. Data collection, management, sharing and influencing policy-makers proactively with long-term monitoring results are key. Knowledge of connectivity thresholds needs to feed into policy decisions.

3.5 Monitoring land-use change

A critical blind spot in much of connectivity monitoring is that we are seemingly focussed on the wildlife movement and tools to do so, but are not adequately tracking land-use change. Land-use change gives us insight into corridor change and erosion, how wildlife become isolated or squeezed into marginal areas, and when, where and how bottlenecks emerge. We need to start developing more sophisticated and realistic ways to monitor, understand and predict change across landscapes: what are the drivers of change; how do government, markets and climate processes impact land-cover trends; how is infrastructure development altering permeability and can we predict change; and how does planning and zoning impact landscape permeability and how do we influence these processes at the right time.



4. ENGAGEMENT STRATEGIES FOR CONNECTIVITY

How are we dealing with production / agricultural space when designing corridors? How do we manage the competing aspirations of people and the need for wildlife movement? How are commodities sectors and government agencies engaged to maintain connectivity?

4.1 Corridor management case studies

Illustrating the agriculture mosaic as a corridor in India. Ashish Bista WWF India

Agricultural farmlands juxtaposed with water bodies and low-density human settlements have the potential to provide passage for movement / dispersal of large-bodied mammals and create a specialized habitat. “Amariya” depicts one such mosaic colonized by tigers amidst sugarcane farmland, after initially dispersing from Pilibhit Tiger Reserve via sugarcane farmlands. However, under such circumstances managers are embroiled in ensuring safety of both animal and human lives. Often rapid response solutions put in place such as once-off fencing of protected areas are done so without understanding their efficacy. Designing corridors and protection will have to depend on wise land-use planning and exploring other feasible and viable options.

Corridors in a highly fragmented and contentious landscape: dealing with process and politics, India. Hiten Baishya WWF India

In a complex mosaic landscape with high levels of wildlife movement and large human population, the complexities and challenges of maintaining connectivity through community support invariably reach far beyond species tracking and environmental processes. The first hurdle is gaining local community and political support, but this failed despite provision of strong evidence and communications campaigns demonstrating the value of corridor protection for both people and wildlife. Data was then used to influence higher levels of government, to which the government then acted on land-use planning and monitoring. The key lessons in this case were: the need to develop comprehensive understanding of sub-national authorities’ values, interest and power; consider options to negotiate with highest political level; recognize the system requires both top down and bottom up interventions and processes; the need for accountability and judiciary support; and with the ultimate goal of partnering with communities.

Addressing key conservation issues within tiger corridors: Maharashtra Tiger Conservation Program, Vidarbha Region Central Indian Tiger Landscape. Chitranjan Dave WWF India

A snapshot of three corridor complexes in central India gives a clear picture of the challenges of reducing threats, maintaining connectivity, and demonstrate the need for active and long-term engagement – as opposed to strict management planning – with non-conservation sector:

Complex A (Melghat – Bor – Pench)

- Dependency of people on forest for NTFP
- Railway developments
- Road widening
- Agriculture development
- Development along state boundary without considering corridor value
- Interstate forest and wildlife offences

Complex B (NNTR – TATR – Umred Krandhla)

- Gosekhurd & Huma Irrigation Projects
- Mining
- NTFP collection
- Human Wildlife Conflict
- Forest fire
- Insurgency

Complex C (Painganga - Tipeshwar -- Chaprala – Pranhita)

- Forest fire
- NTFP collection
- Mining
- Pranhita Chevella Irrigation Project
- Timber extraction
- Insurgency

Most pressing landscape level issues across the three complexes are: rapid infrastructure development; unparalleled HWC profile; economic growth leading urbanization across landscape; agriculture sector undergoing major shift; glorifying vs politicizing wildlife issues; and a fire-fighting approach instead of long-term planning for securing wildlife areas in the long term. Each of these requires a shift away from corridor management planning toward stakeholder engagement strategies.

Learning from the Terai Arc Nepal: a joint venture with communities to gain support for corridors and bottlenecks across the landscape. Prakash Thapa WWF Nepal

The Terai Arc Landscape started out as a large mammal program, and gradually over two decades evolved into a community-centered program and ultimately a cohesive landscape program. A key part of species and habitat recovery has been the identification of corridors and bottlenecks across the landscape, and then the strong community partnerships developed to lead on landscape connectivity. Multiple community enterprises have been developed over many years such that local incomes, and jobs increase as well as adding value to existing local products: community-based tourism; contribution to a community-based conservation fund; sustainable financing and biogas support; HWC management measures (including early warning systems, electric fencing; predator proof pens; mesh fencing); conservation linked enterprises (saw mill and furniture workshop; bel juice; leafplate; essential oil processing) with over 5,000 households benefiting from the enterprises. The impacts of the long-term work are clear: tiger, rhino and elephant populations are all recovering along the TAL. In Khata corridor for example only one tiger was there in 2004, while in 2015 as many as 13 tigers are in the same forest area. Communities now lead on the monitoring of tiger and rhino in the corridor. Two corridors along the TAL – Khata and Lamahi – have also shown sustained increase in forest cover due to community regeneration. Multiple local institutions have also been established to empower and enhance public

services in the marginal communities of the corridors: CFUG-Resource Use and Management, CBAPU-Protection Measures-Forest and Wildlife, Eco-Clubs-Education and Awareness, CFCC-Coordinating Body, Cooperatives-Daily/Monthly savings and Livelihood Support, Citizen Scientists-Monitoring wildlife and Forest Watchers are also the front liners in Conservation. More than 800 forest watchers are mobilized itself by CFUGs for protection and conservation forest and wildlife. They have been allocated by collecting certain quantity of grains or little money as incentives from each users of CF. Habitat, RRT- Reduce HWC, Trade Union-Environmental awareness and work safety.

4.2 Conflicting priorities in corridor areas: conservation vs development

In order to effectively conserve corridors, we need to manage and consider both the human-use and the wildlife-use of land (GOPAL). A no-take/no-development approach is not going to be possible or effective, instead we need to negotiate a balanced solution that ensures wildlife movement and compensates for losses due to development. It is therefore essential to gain political and local support in order for corridor conservation to be successful (GOPAL, YADAV). This might involve taking approaches that ensure local communities benefit from the corridor (resource or monetary incentives). Communicating the benefits of having corridors can help garner local and political support. Governments are also likely to support the establishment and protection of corridors if they provide additional benefits. For example in Malaysia, corridors are also catchment areas that regulate water flow.

4.3 Complexities of farmland corridors

A growing body of evidence reveals that large animals like tigers and elephants regularly use human-dominated areas in unpredictable ways. Treating these areas as corridors involves dealing with the complexities of human-use and development.

There is debate on whether humans and wildlife can peacefully co-exist, however it needs to be recognized that there can be a cost to local communities when these two groups share land and resources (YADAV, GOPAL). Large animals utilizing farmland is a risk since it brings people and animals together in one place and can lead to conflict (YADAV). Therefore, there is a responsibility to manage conflict in these areas as well (and not just in protected areas). This is tricky since corridors are dynamic and animals moving through them will utilize resources in them if they are present (For example, elephants raiding crops or livestock depredation by tigers). It is essential to consider how to manage these corridors such that connectivity is maintained whilst minimizing the cost to locals.

“In many instances, for conflict species and humans intersecting in corridors, we must acknowledge and consider co-occurrence as the guiding principle, not co-existence”

S.P. Yadav
(Chief Conservator of Forests, Uttar Pradesh)

Establishing corridors in human-dominated settings such as farmland is complicated and greatly depends on the cultural perspectives and tolerance levels of local communities. These factors vary in different landscapes for example, farmers in the Indian state of Uttar Pradesh are known have a high tolerance level for conflict whereas in other states, such as Kerala, the government has had to relocate tigers after just a single cow was killed (JOHN-SINGH, WORAH). Sensitizing farmers and other locals to having wildlife around will help to reduce conflict and increase tolerance levels. This could involve providing incentives for allowing wildlife to move through their farmland or providing adequate compensation for losses. It has been found that the tolerance level of local communities is higher when government response to conflict is swift. However, the most appropriate government response in different conflict scenarios needs to be established. Certain measures such as relocating animals could save human lives but result in loss of connectivity (YASUDEV). Fencing will not only restrict movement but also doesn't account for the large population of animals living and moving outside of protected areas (YADAV, CHANCHANI, YASUDEV). There was general consensus among the group that selective fencing around villages could be a good option for reducing the cost of conflict on local communities.



5. CONNECTIVITY POLICY, REGULATION AND GUIDANCE

What are the stand-out examples of government uptake of corridors? Are governments using the scientific data? What does success look like? Do we have the economic arguments and language needed on corridors to talk to governments?

5.1 Corridor policy case studies

Continental corridors: the Australian experience, Darren Grover WWF Australia

The National Wildlife Corridors Plan is a framework for landscape-scale conservation which was released in 2012 to address the problem of habitat loss and fragmentation in Australia. This plan sought to lay a foundation for a new, collaborative, whole-of-landscape approach to conserving biodiversity and emphasizes that healthy, functioning landscapes require connectivity at a variety of scales. It recognizes that establishing a corridor in Australia is a cooperative endeavor and that they need to be designed and implemented in ways that benefit local communities. It also points out that effective corridors: (i) connect across a mosaic of land tenures and land uses without affecting property rights and (ii) assist native species' adaptation to the impacts of climate change. The plan highlights that the design of corridors should manage for potential risks (such as invasive species and fire) and be based on the best available information derived from scientific research, traditional indigenous knowledge and practitioner experience. Notable lessons from the Australian case study are:

- While national parks and other protected areas can serve as anchor points for corridors, the involvement of private landowners, such as farms and cattle stations, is essential, it does incur additional transaction costs;
- Corridors have no additional protection therefore connectivity can still be severed through developments including infrastructure, mines and urban expansion;
- Changes of government can lead to changes on the ground, however, strong community involvement can negate the impact of hostile governments.

Whose right of way? Key legal issues in recognizing and securing corridors with respect to linear infrastructure in India, Millind Pariwakam Wildlife Conservation Trust, India

Various examples in Central India and Eastern Ghats showcase the legal and policy challenges of connectivity – both for wildlife and transport.

Often proposed transport corridors seem on paper to require small, seemingly 'unimportant' / benign forestland for their alignment. This leads to estimates of the scale of impact for wildlife passage at a landscape level to be massively underestimated. There are deficiencies in data used to assess impacts, and appraisal processes are considered rushed or predetermined. Where wildlife are factored in to the design, the resulting mitigation costs are then considered prohibitive, or are unrealistically inflated. Ensuring that balanced decisions are made to achieve nuanced 'right of way' designs for transport and wildlife will require more coordination across agency boundaries in both appraisal and construction phases.

Focusing on three policy issues related to Kosi, Kilpura-Khatima-Surai and Gola corridors, Meraj Anwar WWF India

This case study highlights the policy issues affecting three corridors in India and the importance of working carefully with the government and through government channels to change policy. The main factors that have negatively impacted all three corridors are roads, encroachment, habitat degradation and illegal harvesting/felling. Each of the corridors also faces its own unique problems:

- The Kosi corridor is threatened by expanding resorts and an exponential increase in tourism over the past two decades;
- The Gola river corridor has been impacted by mining of the riverbed;
- The Kilpura-Khatima-Surai corridor is threatened by linear infrastructure including two highways, a railway line and a canal.

WWF India has worked towards implementing policy changes to protect these corridors. Some of the changes include:

- The creation of a silent zone and regulation of property sales within and near the Kosi corridor.
- The designation of the Kosi corridor area as an eco-sensitive zone.
- The regulation of riverbed mining to protect the Gola river corridor and address issues such as bank erosion.
- The proposal for an overpass to protect wildlife in order to reduce the impact of linear infrastructure on the Kilpura-Khatima-Surai.

Government implementation and lobbying processes for landscape connectivity in Malaysia, Siva Elagupillay Malaysia

Several converging factors enable connectivity on the ground. An example is the planning and implementation of the Central Spine Forest (CFS) Master Plan in Malaysia. This plan aimed to create linkages and corridors in order to reestablish and maintain connectivity of four major forest complexes in Peninsular Malaysia. Thirty-seven ecological corridors were identified and connectivity was enabled by conducting land-use planning at national, state and district levels. Land use needs were integrated into the plan and implemented by various stakeholders and agencies at all levels. The establishment of the CFS Master Plan was backed up by a legal framework which mandated the plan to be undertaken by the Department of Town and Country Planning and endorsement by the government was essential to this process. Another important contributing factor was the existence of a proper governance structure at every level for policy, planning and implementation.

Using legal instruments to ‘save’ corridors: an example of recent court cases in India, Mohanraj, WWF India

Using legal processes could be a way to guarantee success in some cases where corridors are threatened by encroachment. However, doing so comes with a time and financial cost. It may be more viable to engage the community from the start or look at alternative solutions which are more collaborative and not as time and resource intensive. A good example highlighting this would be the legal process to secure the Sigur corridor which was threatened by human encroachment driven by increasing human population and tourism. Taking the matter to the courts involved clearly delineating the boundaries of the corridor and the extent of encroachment. The court’s decision was to order that all resorts and private owners give up their land to become a part of the corridor.

5.2 Policy impediments to corridor conservation

Securing corridors is a political process and requires a range of allies including politicians, local community groups, industry and financial institutions. Therefore, it is important to strategically engage with policy makers in order to successfully secure and protect corridors. There are however several political challenges faced when protecting corridors including:

- Existing legislation and policies to protect corridors are not clear and have many loopholes. In the past there have been failures due to falsified impact assessment reports;
- Current corridor / conservation policies do not incorporate development planning;
- Highly specific corridor models from least cost pathways and circuitscape can sometimes be too specific / prescriptive, whereas the bigger, broader and more arbitrary corridors may in fact be better starting points to affect policy change;
- Spatially defined boundaries are required to make court cases, but the corridors are dynamic entities and often cannot be defined;
- Minimal incorporation of development planning into corridor/ conservation policy;
- Minimal consideration of the long-term viability of corridor.

5.3 Planning connectivity

Implementing connectivity on the ground requires three main factors: good data, local / community involvement; and government support. Therefore, it is important to promote connectivity conservation among practitioners, stakeholders, and public. This can be done through: clearly defining the what, how and where-to-where of connectivity; determining the effectiveness and applicability of existing measures such as impact assessments to influence connectivity decisions; and developing an effective stakeholder engagement strategy.

The engagement strategy needs to include clear understanding of four key local features: the social landscape – who are local and who are outsiders; local people’s perspectives around resilience, aspirations and needs; the mechanism to actively engage local people; and the incentives to garner public interest and achieve the mutual goals of development and connectivity.

Having stakeholder and public support will make it easier to advocate for national or sub-national policies that promote effective corridor conservation.

5.4 Critical implementation features

Successful implementation of corridors requires engagement by a variety of people including local communities and government bodies. For example, local groups such as honey keepers had to be engaged during habitat and corridor restoration for brown bears in Spain.

Corridors cover many divisions and therefore come under the jurisdictions of different government bodies and usually there is a variety of different stakeholders. It is therefore important to appoint nodal officers and have a team focusing on each corridor (ELAGUPILLAY). All officers in relevant government departments need to be engaged and informed so that work can continue irrespective of transfers, and it is also important to engage local level officers to raise their awareness of connectivity (NAYAK). Line staff need to be engaged as well since not all of the land comes under forest areas therefore several government departments will need to cooperate (NAYAK). Audits of corridors related with national / international recognition could be effective since corridors don’t usually just fall under one jurisdiction (YADAV).

5.5 What does an ideal policy look like?

North Asia and Australia

The countries discussed were Russia, China, Mongolia, and Australia. Australia has a developed corridor policy and is ahead of the other three countries in this respect. China, Mongolia and Russia however no current policy on them. A greater understanding of corridors could be facilitated if the IUCN could create an international standard that could be adapted more locally.

In Mongolia, two laws include corridors (EIA law and Protected Area law). In Russia corridors are treated as a part of the protected area network. There are ongoing discussions about the establishment of a green belt that connects all the protected areas of the region (China to Mongolia to Russia to China). However, this is not considered a priority by the three countries and there are several barriers that need to be overcome before this can happen. One big issue is the border fences in Russia which greatly restrict movement. Additionally, it will be difficult to get all three countries to work together effectively.

South Asia

There are eight different policies that enable corridors on the ground in India. These policies however are not strong or clear enough and developers are managing to find their way around the existing policy. A real legal framework that recognizes and delineates corridors at a local and national level is therefore required. This requires local support as well as financial support and resources from relevant government departments to effectively implement policy. In India, corridors are affected by development at two levels – district planning (when corridors just disappear) and site-level interventions so it is important for policies to be integrated into the district plan and implemented at the district level.

Areas of Connectivity Conservation (ACCs) could be established and recognized, these can allow for certain kinds of land use whilst maintaining connectivity.

Southeast Asia

In the past, development has occurred even in protected areas that are supposed to have the protection of the government. It is therefore important for all stakeholders to recognize corridors, not just the Ministries of Environment. The key stakeholders need to be identified and then a multi-stakeholder platform with multiple ministries (e.g. transport, planning, finance, agriculture, and environment) needs to be established. The protected areas and corridors can then be collectively recognized and established based on the data available.

A national level policy then needs to be implemented which determines who is responsible for protecting the corridors. All southeast Asian countries except Myanmar currently have a corridor policy however, there are issues with implementation on the ground in many countries. For example, Malaysia has a good corridor policy but there is minimal on-ground implementation.



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6. INSIGHTS FROM LONG TERM CORRIDOR PROGRAMS

Various corridor programs globally highlight lessons, challenges, and opportunities for tiger corridors. How have these programs overcome development pressures and adapted to changing contexts and human populations? What have been the standout strengths of these programs? Are they well placed to tackle emerging challenges of competition for space?

6.1 Long term corridor case studies

Central Sumatra's "RIMBA" corridor - challenges and opportunities for corridors implementation in a commodities landscape, Oki Hadian, WWF Indonesia

In 2012 there was a presidential decree which mandated the establishment of five ecosystem corridors to maintain movement for tigers, elephants, and birds in Sumatra. These corridors were delineated after conducting spatial planning based on several factors (such as key biodiversity areas, important bird areas, and distribution of flagship species). One of the five corridors is the RIMBA corridor in Central Sumatra which is a landscape dominated by industrial crops (oil palm, acacia, rubber, and eucalypt), agriculture and mining. There are several challenges associated with implementing this corridor. It is a large area (covering three provinces) and requires dealing with different local governments which have different regulations. However, the implementation of the RIMBA corridor also highlights several opportunities including working with advanced spatial technology. There is also strong support from the government which is open to working with NGOs and sharing data.

Qinling Tunnel Panda Corridor, China: a conservation success of 10+ years of effort, Hui Wan, WWF China

The building of a national road in the 1970s led to the fragmentation and degradation of panda habitat. In 2000, a new road and tunnel was built which provided an opportunity to reconnect the fragmented habitat. The Qinling Tunnel corridor restoration project was then launched by WWF and the Shaanxi Guanyinshan Nature Reserve. The main activities of the project included baseline surveys (to understand the status of panda subgroups in the area), mapping, habitat restoration, local community engagement, enforcing bans on using the old road and wildlife monitoring. As a result of this work, it was found that giant pandas were utilizing the corridor (along with a variety of other mammals and birds) and the ecological distance between panda subgroups had decreased.

The Russian "Tiger Econet" initiative: optimizing for landscape connectivity, Alexei Kostyria, WWF Russia

The Tiger Econet initiative looked at connectivity as a network instead of a linear concept. ECONET or ecological networks, are systems of protected areas and connecting them ecological corridors, buffer zones and other areas with appropriate conservation regime. There are estimated to be about 540 Amur tigers in Russia. Their range largely coincides with the presence of Koran pine-broadleaf forests which have been heavily degraded by logging and fires and core tiger habitat coincides with optimal habitat for prey species such as red deer and wild boar. Only a small portion of the Amur tiger's range comes under protected areas. There are however more planned protected areas which cover a larger part of their range as well as HWC response teams, rehabilitation centres and model hunting leases. Currently, protected areas in Russia (including nature reserves, provincial wildlife refuges and planned PAs) covers about 21% of the Amur tiger's range and 38% of the core zone. And 14% of potential habitat.

Reflecting on the Bhutan national corridors framework, Dechen Yeshi, WWF Bhutan

In 2008, Bhutan declared biological corridors as a "Gift to the Earth". There are currently eight corridors that cover about 9% of Bhutan's land area and the territorial divisions are mandated to manage these corridors. A Framework on Biological Corridors was developed in 2010 which recommended operationalization of the corridors through management plans. The legal status of the corridors in Bhutan is now equal to that of a protected area however, there are still threats like human-wildlife conflict, illegal wildlife trade and development activities. Awareness and capacity building is crucial for the management of the corridors.

National standard for wildlife corridors along the highways and railways in high mountain areas of Mongolia, Chimeddorj Buyanaa, WWF Mongolia

A national mandatory new standard for "Construction of Wildlife Crossings (under and over pass and level crossing) along the road and road infrastructure in Mountainous areas" has been officially issued by Mongolian Agency for Standardization and Metrology with financial and technical support from WWF Mongolia. Mining is rapidly developing in Mongolia and is expected to remain as one of the leading sectors in the coming years. The development of mining associated linear infrastructure also brings high risks for fragmentation of wildlife migration routes and habitats. WWF-Mongolia, the Ministry of Road and Transportation, the Ministry of Nature, Environment and Tourism and biologists have actively worked on the development and approval of national standards on wildlife passages along roads and railroads that reflects wide ranging research findings and recommendations. The environmental community emphasizes that the implementation of the above standards is a good starting point for preventing fragmentation of habitats and migratory routes of globally endangered wildlife species.

Securing & restoring elephant corridors in India, Sandeep Tiwari, IUCN Asian Elephant Specialist Group

There are currently at least 101 corridors in India, a substantially larger amount than there were in 2005 (88 corridors). However, these corridors are threatened due to development and encroachment and are becoming narrower, with at least seven corridors being completely impaired. Currently, in India:

- 13% of corridors are totally under forest compared to 24% in 2005
- 22% of the corridors are free of human settlements
- 29% of the corridors have encroachment
- 66% of corridors contain agricultural land
- 66% have highways
- 25% have railway lines
- 11% have canals
- 12% are affected by mining and boulder extraction
- 47.5% of corridors are within or touching Protected Areas

In order to properly secure these corridors there needs to be: proper demarcation / delineation of corridors; a legal framework to protect; increased awareness amongst the public and policy makers; and monitoring of land-use change and corridor usage.

There are four suggested models to secure corridors: public initiative (educating and empowering local stakeholders / community to push for policy protecting corridors); private purchase; government acquisition; community securement (community owned lands set aside through easements or bilateral benefit sharing).



An aerial photograph showing a dirt road that winds through a vast, dense forest. The forest is a deep green color, and the road is a light brown. In the background, there are several layers of mountain ranges, with the furthest ones appearing hazy and blue. The sky is a pale, overcast grey.

7. EMERGING FIELDS IN CONSERVATION CONNECTIVITY

How is climate change being factored into corridor planning? How are landscapes working with agriculture and commodities to maintain connectivity? How are we future proofing our corridors solutions to keep pace with land use changes? Do national corridor standards and guidelines have the teeth needed?

7.1 Emerging fields in conservation connectivity case studies

A toolkit to identify critical linkages across tiger landscapes, Ashley Scott Kelly, Hong Kong University.

This case study focused on how to evaluate sites for development based on environmental metrics and new conservation agreements. For urban and landscape resilience, we must ensure the critical and innovative deployment of conservation and impact assessment instruments and tools, including the measure of biodiversity, vulnerability, and ecosystem services. We need to consider factors like land-use and zoning and need to conduct habitat modelling before any developments are undertaken. For example, habitat modelling for the proposed Dawei road linkage shows the road moving right through an optimal corridor for all nine modelled species. Assessment of ecosystem services and the indirect impact of development also needs to be considered in the planning process. Road design and sustainability is dependent on certain ecosystem services such as prevention of landslides and flooding, so for the infrastructure to be sustainable, ecosystem services need to be factored in. Sustainable infrastructure would include measures such as minimizing the amount of waste soil to prevent sedimentation of streams and rivers, wildlife barriers and creation of safe wildlife crossings and reducing erosion by creating bio-engineered slopes (vegetated geo-textile slopes walls).

The toolkit highlights three major components: (i) biophysical data, (ii) development information and, (iii) team expertise (the expertise of the team using the tool). Development is more sustainable when there is more biophysical, environmental and development data available and considered in the planning process. Some of the current problems that need to be overcome include poor transparency of the planning process, site work being conducted ahead of impact assessments and lack of data. Some ways to overcome lack of data include modelling, running scenarios and transposing data from other known sites.

Concepts, models, and assessments of climate-wise connectivity globally, Anika Keeley, University of California

- It is important to account for climate change when looking at connectivity and corridors, this can be done in several ways:
- Connecting climate analogs (sites with today's climate matched with sites that may have a similar climate regime in the future, making the two geographically separated sites analogs to one another);
- Reducing climate velocity (speed at which a population would have to move to keep up with climate change) in corridors. This can be done by maximizing microclimate diversity and incorporating refugia in corridors; and
- Establishing wide, live-in corridors.

Some climate-based connectivity models include: climate gradient corridors (these corridors follow climate gradients rather than linear paths between two Protected Areas / habitats); latticework corridors (a corridor system that connects both across an elevational / climate gradient as well as within elevational bands); land-facet corridors (these corridors are delineated based on landscape units with relatively uniform topographical and soil traits) rather than current land cover maps (which are likely to change in the future due to climate change) since the interaction of these units with future climate change is likely to influence future vegetation and human land-use); naturalness-based corridors (prioritize areas with the least human disturbance); riparian corridors; carbon stock corridors (these aim to maximize the amount of biomass contained within the corridor).

Locating priority areas for fruit tree plantations to enhance brown bear connectivity in the Northwest of Spain, Teresa Goicolea, Polytechnic University of Madrid

Three main factors need to be considered in the planning process when undertaking restoration work to enhance connectivity:

- Connectivity capacity: areas with the highest current contribution to connectivity of the species;
- Restoration efficiency: areas in which reductions in resistance would be most beneficial to enhancing connectivity and where the least amount of effort will result in the largest increase in connectivity; and
- Trophic value: the availability and importance of various food resources consumed by the target species in different areas.

Areas where all three factors coincide should be prioritized for restoration. In the case of the brown bear corridor in Northwest Spain, connectivity capacity and restoration efficiency were high but trophic value in the corridor area was low. Due to low trophic value in the corridor, it was reforested with trees which were important food sources for the bears. The conservation and maintenance of the restored vegetation is guaranteed for a minimum period of 20 years via Landscape Stewardship Agreements. This work was conducted in conjunction with awareness-raising activities to gain support from the local community.

IUCN guidelines for connectivity: Connectivity Conservation Specialist Group (CCSG), Melly Reuling, Center for Large Landscape Conservation and Connectivity, IUCN

For connectivity to be effective and contribute to conservation there needs to be standards and guidelines. This would require: defining spatially explicit targets; establishing standards of practice (such as monitoring & spatial design); planning frameworks (should be enduring and recognized by governments and legally binding); development of incentive-based approaches; recognition of best practice; and a networked learning community.

On behalf of the IUCN World Commission on Protected Areas (WCPA), the Connectivity Conservation Specialist Group (CCSG) is developing guidelines for safeguarding ecological corridors in the context of ecological networks for conservation. A series of consultations was held around the world in 2017 and these guidelines are being developed based on feedback from the consultations, collaboration among a core group of lead authors and experts. The purpose is to clarify and standardize approaches for protecting the physical spaces that connect protected and conserved areas, enhance comprehensive management through overarching ecological networks, and thus improve large-scale conservation outcomes.

7.2 A Coalition for corridors

Wildlife corridors in India are threatened by linear infrastructure, extractives and urbanization. Given how numerous and expansive corridors are, it is impossible for any single organization to monitor threats and develop timely interventions to arrest further degradation. Therefore, an initiative has been proposed to create a coalition of India's major national and international conservation organizations, working with local NGOs and community-based organizations (CBOs) to secure wildlife corridors. This coalition aims to:

- (i) develop a dynamic web-based platform with corridor profiles based on state-of-the-art modelling and monitoring;
- (ii) build community partnerships for corridor stewardship; and
- (iii) initiate actions to promote forest land restoration and protect and restore corridors through advocacy, legal and technological solutions.

The Coalition for Corridors can drive several breakthroughs in connectivity conservation planning and practice. This includes expanding wildlife and habitat monitoring over many thousand square kilometers and using the data obtained to empower conservationists and managers to re-orient forest management practices, and influence land use planning and infrastructure development. Such a collaboration will unify and amplify voices for corridor conservation, while fostering synergy. Additionally, partnerships with CBOs will create opportunities for equitable and sustainable local stewardship of corridors, including managing farmlands, plantations and river-edges to enable wildlife movement.

7.3 State of the art corridors report / corridors atlas

There should be a Strategic Action Plan, which outlines the different corridors and their corridor profiles, and the actions required to establish and protect them across tiger range countries. The plan would address how different governments would go about taking action to establish and protect corridors. All relevant organizations could collectively work on developing and implementing this. It could be a tiered system with large and small organizations and individuals contributing (YASUDEV, CHANCHANI). This could also play to the strengths of the different groups for example; monitoring could be conducted by certain groups that are more experienced in that area (GHOSE).

The plan would be an aggregation of relevant data that would be important when considering action for corridors (CHANCHANI).

A system for sharing data therefore should be implemented. The data could be obtained from a variety of sources including civil society groups and universities. There could be a peer review / update system for proposing new corridors to reduce the likelihood of disagreement between different groups (RAMAKRISHNAN). The process could start with analyzing published matter on corridors to understand where the gaps are (SINGH). It is important to appoint representatives that work on each corridor whose roles will include the following:

- Observe current / changes in land use
- Monitor corridors for animal use
- Sensitize the local politicians and come up with a plan to secure the corridor
- Build a stakeholder base

An annual corridor assessment will be required to keep track of the state of each corridor, this could be a state-of-the-art corridors report (PARIWAKAM, GHOSE). Such a report would require collective funding from the various participating NGOs (TIWARI).

7.4 Climate change and emerging issues

The need to consider climate change when looking at connectivity conservation is clear. These are two emerging streams that need to co-develop in order to be effective. The key factors that need to be considered when looking at climate change are very similar to those that need to be considered for regular natural resource management work. Some of the key issues to consider mirror those in climate adaptation discourse:

- Integration of various parameters into corridors planning;
- Co-benefits of corridors for humans and ecosystem services;
- Green belts – carbon sinks, zoning;
- Mapping and monitoring changing temperatures;
- Species range shift impacts;
- Natural disaster intensification impacts;
- Monitoring vegetation shifts;
- Severe weather impacts to wildlife and what it means regarding human-wildlife conflict;
- Invasive species;
- Changes in agricultural practices / land use;
- Ecosystem resilience to change;
- Tools to educate the government about climate impacts;
- Complexity of pushing for corridors of today versus corridors of the future;
- Study of irreplaceability of links; and
- Historical species distributions to study climate change impacts.

8. ANNEX 1: LANDSCAPE CONNECTIVITY WORKSHOP AND PARTICIPANTS' LIST

The format of the workshop was targeted presentations followed by discussion labs in groups to explore innovations presented and their applicability to connectivity landscapes. Presentations were selected based on the inventiveness of the topic, the innovativeness of the action, or the standout success and strength of the approach at its site of application.

The primary aim of the workshop was to develop an overarching corridors strategy for tiger landscapes to ensure the long-term maintenance of landscape metapopulations. By bringing WWF landscape practitioners and external specialists together to pool knowledge and design a future-focused approach to maintaining landscape connectivity, we also sought to further the understanding and knowledge on implementation of corridor conservation across the region.

The specific objectives of the workshop were to:

1. Present contemporary innovations in key aspects of corridors work globally: identification, performance monitoring, solutions and actions.
2. Discuss applicability of global approaches to tiger landscapes, potential challenges and pilot sites, resource or capacity limitations.
3. Develop a road map to a Corridors Strategy, what steps and actions need to be taken immediately, what resources and partnerships are needed.
4. Form a Corridors Working Group to take the strategy to fruition.

Participants

Internal

Participation included WWF staff from tiger, snow leopard, panda, elephant, rhino and orangutan landscapes.

External

External participation also included multiple specialists from global centers as well as Indian National scientific and government agencies.

Name	Organization
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Hiten Kr Baishya	WWF India
Gantulga Bayandonoi	WWF Mongolia
Ashish Bista	WWF India
Boominathan	WWF India
Thijs Bredenhoff	WWF Greater Mekong
Ashley Brooks	WWF Tigers Alive
Chimeddorj Buyanaa	WWF Mongolia
Pranav Chanchani	WWF India
Mark Darmaraj	WWF Malaysia
Soumitra Dasgupta	Ministry of Environment, Forests and Climate Change, India
Chittaranjan Dave	WWF India
Dipankar Ghose	WWF India
Teresa Goicolea	Polytechnic University of Madrid
Darren Grover	WWF Australia
Jyotirmay Jena	WWF India
A.J.T. Johnsingh	Advisor to WWF India and the Nature Conservation Foundation
Annika Keeley	IUCN Connectivity Conservation Specialist Group
Sivananthan Elagupillay	Advisor to WWF Malaysia
Fan Zhiyong	WWF China
Rajesh Gopal	Global Tiger Forum
Gaurav Gupta	WWF Myanmar
Oki Hadian Hadadi	WWF Indonesia
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Sabita Malla	WWF Nepal
Mohanraj	WWF India
Mardy Pov Ouch	WWF Cambodia
Regan Pairojmahakij	WWF Thailand / Myanmar
Milind Pariwakam	Wildlife Conservation Trust
Liu Peiqu	WWF China
Qamar Qureshi	Wildlife Institute of India
Uma Ramakrishnan	National Centre for Biological Sciences, India
Melly Reuling	Centre for Large Landscape Conservation
Nitin Sekar	WWF India
Tridip Sharma	WWF India
Prakash Thapa	WWF Nepal
Sandeep Tiwari	Wildlife Trust of India
Divya Vasudev	Wildlife Conservation Society India
Sejal Worah	WWF India
Madeleine Xavier	WWF Tigers Alive
Hui Wan	WWF China
S.P. Yadav	Uttar Pradesh Forest Department
Dechen Yeshe	WWF Bhutan

9. ANNEX 2: GLOBAL CORRIDORS CASE STUDIES

[This snapshot report](#) provides a series of case studies on the conservation and restoration of corridors worldwide. Ultimately, this report seeks to provide an overview of actions and interventions to improve landscape connectivity based on current literature and corridor preservation projects and the types of solutions being applied to maintain them.



10. REFERENCES

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