A landscape-based conservation strategy to double the wild tiger population

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Abstract

In an unprecedented response to the rapid decline in wild tiger populations, the Heads of Government of the 13 tiger range countries endorsed the St. Petersburg Declaration in November 2010, pledging to double the wild tiger population. We conducted a landscape analysis of tiger habitat to determine if a recovery of such magnitude is possible. The reserves in 20 priority tiger landscapes can potentially support >10,000 tigers, almost thrice the current estimate. However, most core reserves where tigers breed are small and land-use change in rapidly developing Asia threatens to increase reserve and population isolation. Maintaining population viability and resilience will depend upon a landscape approach to manage tigers as metapopulations. Thus, both site-level protection and landscape-scale interventions to secure habitat corridors are simultaneous imperatives. Co-benefits, such as payment schemes for carbon and other ecosystem services, should be employed as strategies to mainstream landscape conservation in tiger habitat into development processes.

Introduction

The number of wild tigers (*Panthera tigris* Linnaeus 1758) has been reduced from an estimated 100,000 in the early 1900s to around 3,600 adults scattered as small populations across the range (Global Tiger Recovery Program 2010). In this, the year of the tiger in the Chinese calendar, the Heads of Governments of the 13 tiger range countries (hereafter range countries) adopted an ambitious plan (hereafter, the St. Petersburg Declaration), to recover and double the range-wide wild tiger population. The aim of this article is to provide the first scientific analysis of the feasibility of this political commitment, and show why a landscape-based strategy is essential to achieve this population recovery target.

Five years ago, conservation scientists identified a suite of Tiger Conservation Landscapes—large blocks of connected tiger habitat that can support at least five tigers and where tiger presence had been confirmed in the past 10 years—as the best options for securing tiger metapopulations for long-term conservation (Dinerstein *et al.* 2006). A key component of that recovery strategy is the protection of core breeding populations. More recently, Walston *et al.* (2010) identified 42 tiger "source sites," representing a mere 6% of the recent range and 70% of the current estimated tiger population, which must be secured to stop the current downward trend. They draw a parallel with the African rhinoceros recovery program of the 1980s and advocated that after these source sites are secured from poaching of tigers and prey, then should attention and resources be allocated to conserving the corridors and adjacent habitats that connect and surround the source sites.

In this article, we show that while source sites alone will not meet the stated range-wide goal of doubling the population, with effective protection of tigers and prey the current range-wide reserve system can. In addition, we argue the tiger's ecological and demographic requirements, and genetic consequences of isolated tiger populations, demand a landscape approach that goes beyond reserve boundaries. We then examine the socio-political and policy implications for tiger conservation that embraces the more comprehensive approach of a landscape-based strategy. We also extend the discussion to how such approaches would be relevant to large vertebrates in other parts of the world.

Methods

Analysis of conservation capacity of tiger habitat

Using ArcGIS, we intersected the World Database on Protected Areas (WDPA; UNEP & IUCN 2009) with the Tiger Conservation Landscape map (Dinerstein *et al.* 2006) to determine the number of reserves within tiger landscapes. We used all International Union for Conservation of Nature (IUCN) category I–VI reserves, whether designated or proposed, in the analysis, but discarded cultural and national heritage sites and removed several overlapping reserves. Adjacent reserves were amalgamated to represent larger reserve complexes (Figure 1).

Table 1 Potential tiger densities (tigers/100 km^2) assigned to biomes, or major tiger habitat types

Biome/habitat type	Potential population density	Potential breeding female density
Rainforest/tropical evergreen forests[1]	3	1
Dry deciduous forests[1]	10	3.3
Subtropical pine forests[2]	1	0.3
Broadleaf temperate forests[1]	1	0.3
Alluvial savanna/grassland[1]	15	5
Mongolian steppe/open woodland[3]	0.6	0.2
Amur steppe[3]	0.6	0.2
Thorn scrub/woodland[4]	10	3.3
Mangrove[1]	3	1

[1] Densities based on Karanth *et al.* (2009).
[2] Subtropical pine forests are narrow or patchy habitats adjacent to Broadleaf Temperate forests and tiger densities were considered to be similar.
[3] Density estimated from Miquelle *et al.* (2010a).
[4] Considered to be similar to densities in Dry Deciduous forests.

We intersected the reserve layer with a biome layer to determine the extent of each biome that is included within each reserve. The biomes represent different tiger habitat types (Table 1). The intersected layer of the extent of major habitat types within each reserve was used to calculate the potential tiger numbers that each reserve could support, because a single reserve can have more than one major habitat type, with each supporting different tiger densities. Tiger density estimates are from Miquelle *et al.* (2010a) and Karanth *et al.* (2009) (Table 1).

The previous range-wide Tiger Conservation Landscape analysis (Dinerstein *et al.* 2006) identified 20 Global Priority Tiger Conservation Landscapes. These are the landscapes with the highest probability of long-term persistence of tigers and are the best representations of tiger habitats across the realms of the tiger range (Figure 1). We selected the reserves that fall within or adjacent to these 20 priority Tiger Conservation Landscapes to calculate the potential tiger populations these reserves can support.

In some cases, two or more reserves were located adjacent to one another. These were considered to be reserve complexes and the tiger populations in the individual reserves that comprised such complexes were summed to obtain an aggregated population size for the entire complex.

Results

There are 324 reserves embedded within all Tiger Conservation Landscapes covering >380,000 km^2 (Table 2).

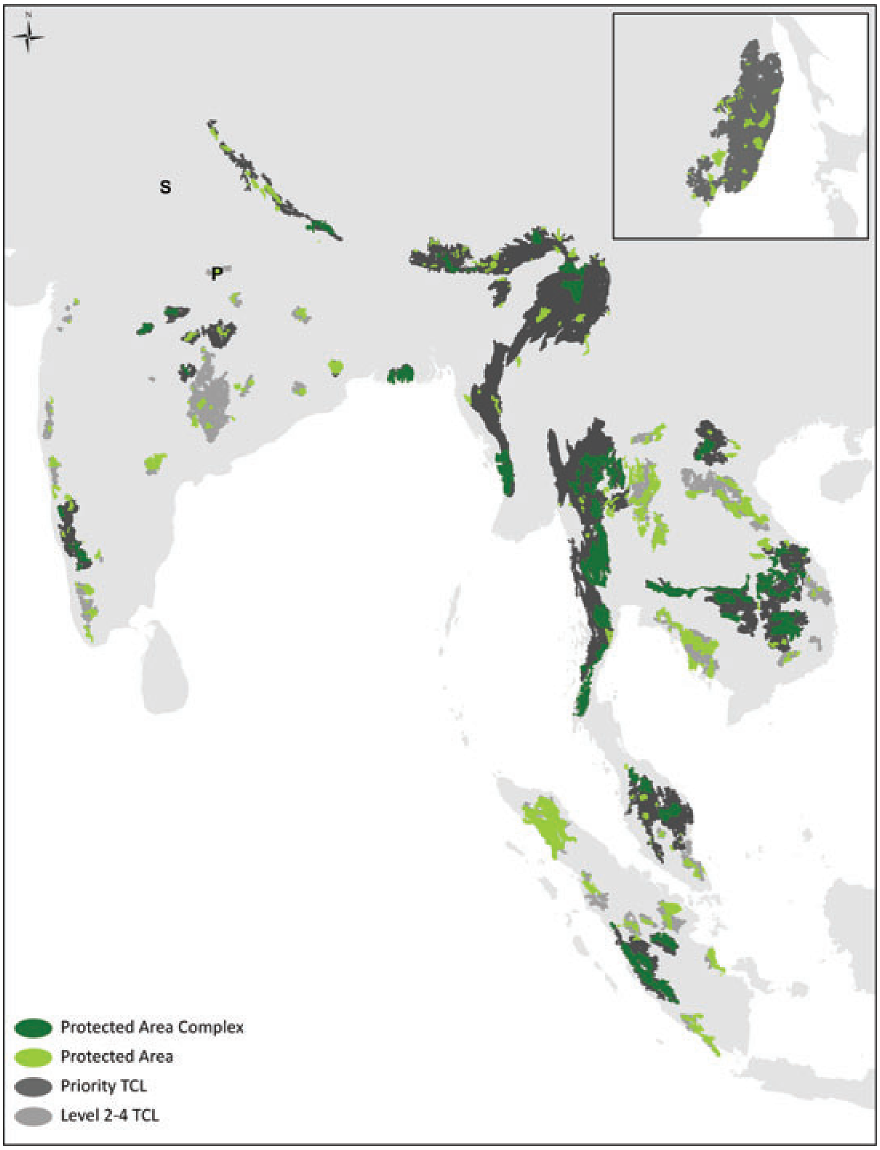

Figure 1 Tiger Conservation Landscapes and protected areas in the tiger range. Protected area complexes represent protected areas that are adjacent to each other in and around the priority Tiger Conservation Landscapes. The inset shows the Tiger Conservation Landscape that covers the Russian Far East and Changbaishan region of China. Data based on Dinerstein *et al.* 2006. The protected areas in the respective Tiger Conservation Landscapes are connected by habitat, with potential to facilitate tiger dispersal between them, and represent possible metapopulations (refer Sanderson *et al.* 2006 for detailed maps). "S" and "P" refer to locations of Sariska and Panna Tiger Reserves mentioned in the main text.

Based on potential densities from Miquelle *et al.* (2010a) and Karanth *et al.* (2009) (Table 1), these reserves can potentially support >15,000 tigers at capacity, including >5,000 breeding females. Of these reserves, 169, representing about 69% of the spatial extent, fall within the priority Tiger Conservation Landscapes, and can potentially support almost 10,500 tigers, including about 3,400 breeding females.

Sixty-nine reserves (including reserve complexes) are large enough to support >5 breeding females and can potentially support a total population of >9,900 tigers at capacity (Table 2). Twenty-seven reserves are large enough to support >25 breeding females, of which 23 are complexes composed of two to 17 contiguous or adjacent reserves, with just eight complexes being able to support >100 breeding females (Figure 2). The other 42 reserves

Table 2 Numbers of protected areas and protected areas complexes in Tiger Conservation Landscapes. The estimated total tiger numbers that can be potentially supported in the protected areas (PAs) include all adults, or only breeding (territorial) females

	All Tiger Conservation Landscapes	Priority Tiger Conservation Landscapes
Total number of PAs or PA complexes	324	169
Total area of PAs or PA complexes (km^2)	386,217	264,737
Total number of tigers in PAs or PA complexes	15,321	10,468
Total number of breeding females in PAs or complexes	5,074	3,462
Number of protected areas/complexes in priority Tiger Conservation Landscapes with capacity to support >5 breeding female tigers		69
Potential tiger population in protected areas/complexes (in priority Tiger Conservation Landscapes) with capacity to support >5 breeding female tigers		9,948

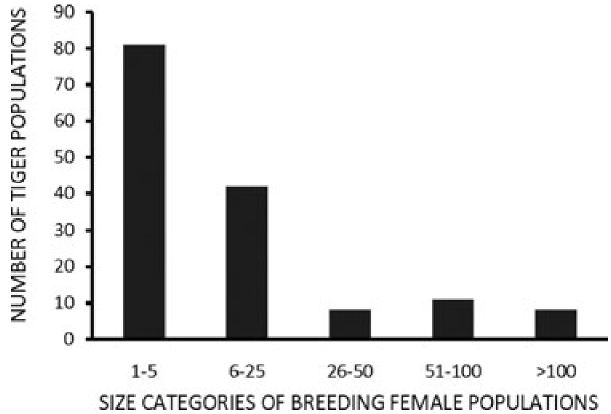

Figure 2 The numbers of breeding female populations in different size categories that can be supported in the protected areas located in and around the priority Tiger Conservation Landscapes. The population sizes represent the potential number of breeding female tigers that can be supported in the protected areas. Estimation details are provided in the text.

are large enough for 6–25 breeding females, and can, on average, support 40 tigers ±19 standard deviation (SD) (total adult population), which is similar to the current populations in many tiger reserves, including those in India (Carbone *et al.* 2001; Karanth *et al.* 2004).

Discussion

In the midst of a crisis, the temptation among conservationists is to "circle the wagons" and protect what we can, which often consists of a limited set of parks and reserves, or in order to address the current tiger crisis, "source sites" (Walston *et al.* 2010). However, we argue that focusing on these isolated sites may reduce the immediate risk of population extirpation within them, but neglecting corridors in a region experiencing rapid habitat loss (Hansen *et al.* 2008), will not sustain tiger ecology, behavior, and genetics. Thus, while protection of core habitat is important, a successful tiger recovery program should be more ambitious than protecting numbers.

Our analysis indicates that the reserves embedded in the priority Tiger Conservation Landscapes represent sufficient habitat to support a doubling—or even a near-tripling—of the range-wide population. While 28 reserves in priority, landscapes, including complexes, can support tiger populations with >25 breeding females; the 41 other reserves can potentially support 5–25 females. The latter reserves are necessary to achieve the regional goal of doubling the wild tiger population.

Recovering wild tiger populations: An overview of biological parameters

Genetic concerns of isolated tiger reserves

Several tiger populations have already undergone severe genetic bottlenecks (Mondol *et al.* 2009) and might already be inbred (Kenney *et al.* 1995). Genetically, most if not all of these populations could be too small for long-term viability and persistence (Frankham *et al.* 2010; Traill *et al.* 2010). A strategy that maintains connectivity will allow greater gene flow between subpopulations and mitigate further inbreeding depression in these populations without the costs of translocations (Johnson *et al.* 2010). This strategy is also necessary to achieve other important conservation targets, such as, to increase the resilience of tiger populations and maintain the natural ecology and behavior of tigers for long-term persistence.

Role of landscape connectivity in population recovery

The historical demography of tigers provides strong evidence that a population doubling is possible in the context of large landscapes where habitat connectivity allows for tiger ecology to persist. The jungles of lowland Nepal and northern India were once continuous along the base of the Himalayas and supported dense populations of tigers and tiger prey (Seidensticker *et al.* 2010). In 1938, during a hunt in what is now the eastern section of Chitwan National Park, Nepalese royalty and their guests shot 120 tigers over a 2-month period (Smythies 1942). For perspective, the current total population of adult tigers in all of Nepal is estimated at 121 (Government of Nepal 2010). Royal hunts rotated among different areas—and massive hunts were rare—allowing local tiger populations to replenish, as evident from the large numbers killed in the same area within 5-year intervals (Sunquist *et al.* 1999).

Tigers can disperse over 100 km from their natal areas to establish territories, and immigration across the landscape of contiguous, suitable habitat likely played a large role in population recovery (Sunquist *et al.* 1999). However, tigers are reluctant to cross more than a few kilometers of unsuitable land cover (Smith 1993). Without connectivity, tiger populations might not have rebounded in the hunted areas. Below we provide evidence from recent events to indicate how habitat connectivity contributes to population recovery and persistence.

In Nepal, reserve protection effectively ceased between 2002 and 2006, because of civil conflict, allowing poachers greater access in Sukla Phanta Wildlife Reserve and Bardia National Park. Populations crashed in both reserves, from 27 adults in 2005 to eight in 2008 in Sukla Phanta, and from 32–40 to 18 in Bardia (Government of Nepal 2010); yet, neither population was extirpated. Both reserves are linked to tiger reserves in India via corridors used by tigers (Wikramanayake *et al.* 2010a; Figure 3A), which likely allowed replenishment. Population viability models using field data from Indonesia also show that maintaining connectivity between tiger populations in larger landscapes can offset losses from poaching and increase population persistence (Linkie *et al.* 2006).

In the 1940s, tigers nearly disappeared from the Russian Far East. Dispersal of tigers from northeastern China, where large numbers of tigers remained at the time, is believed to have contributed to their subsequent recovery (Miquelle *et al.* 2010b). Recently, habitat corridors across the Sino-Russia border allowed tigers to disperse from the Russian Far East and reestablish a population in the Changbaishan Mountains of northeastern China, where they had been extirpated by the 1990s.

In India's Nagarahole National Park, a camera-trap program between 1991 and 2000 indicated that tiger densities ranged from 7.3 to 21.7 tigers/100 km^2, marked by frequent turnover of individuals due to mortality and dispersal from and into the park (Karanth *et al.* 2006). Despite the threefold fluctuation, the population was considered healthy and resilient (Karanth *et al.* 2006). Nagarahole is embedded within a landscape across the Nilgiri range in the western Ghats and connected to other reserves by habitat used by tigers (Figure 3B). Population resilience in Nagarahole may be maintained by metapopulation dynamics associated with its connectivity to other reserves supporting tigers in this landscape, which has close to 300 tigers. The extirpation of tigers from Sariska and Panna, two of India's premier tiger reserves, in 2005 and 2009, respectively (Gopal *et al.* 2010), is evidence of how the lack of connectivity can preclude tiger population recovery and recolonization. Because neither is connected to other reserves through habitat corridors, the Indian government had to transport tigers by helicopter to attempt to reestablish populations in these reserves.

Maintaining metapopulations in a low-density species

Territory size of tigers is correlated with prey densities, and the number of territories held by breeding female tigers can determine the number of tigers in a given area (Karanth *et al.* 2004; Miquelle *et al.* 2010b). Tiger densities vary by a factor of 40: from <0.5/100 km^2 in the temperate forests of the Russian Far East to >20/100 km^2 in the prey-rich alluvial floodplains and riverine forests of India (Ahmed *et al.* 2010). This aspect of tiger biology has implications for recovery, illustrated by contrasting the situation at these two extremes of tiger density.

The largest strictly protected reserve in the Russian Far East is 4,000 km^2, yet it supports <30 tigers, and most of the estimated 450 tigers there live outside the reserve (Miquelle *et al.* 2010b). A reserve of the same size in the prey-rich Indian and Nepal habitats could potentially support 800 tigers. Therefore, tiger recovery in the Russian Far East will require maintaining vast landscapes. In the Indian subcontinent, because of habitat fragmentation, few large, intact habitat areas remain that can support large tiger populations. Here, the strategy must be to protect reserves with breeding tigers and connect them across the human-dominated matrices to allow the small populations to form metapopulations.

Challenges to maintaining landscape connectivity

Tiger recovery requires reversing the decline in numbers. Protecting tigers and their prey from poaching is an imperative, and the continuing loss of tigers is the most visible and visceral metric. The less obvious, but equally vital concern is the swift conversion of natural habitat in

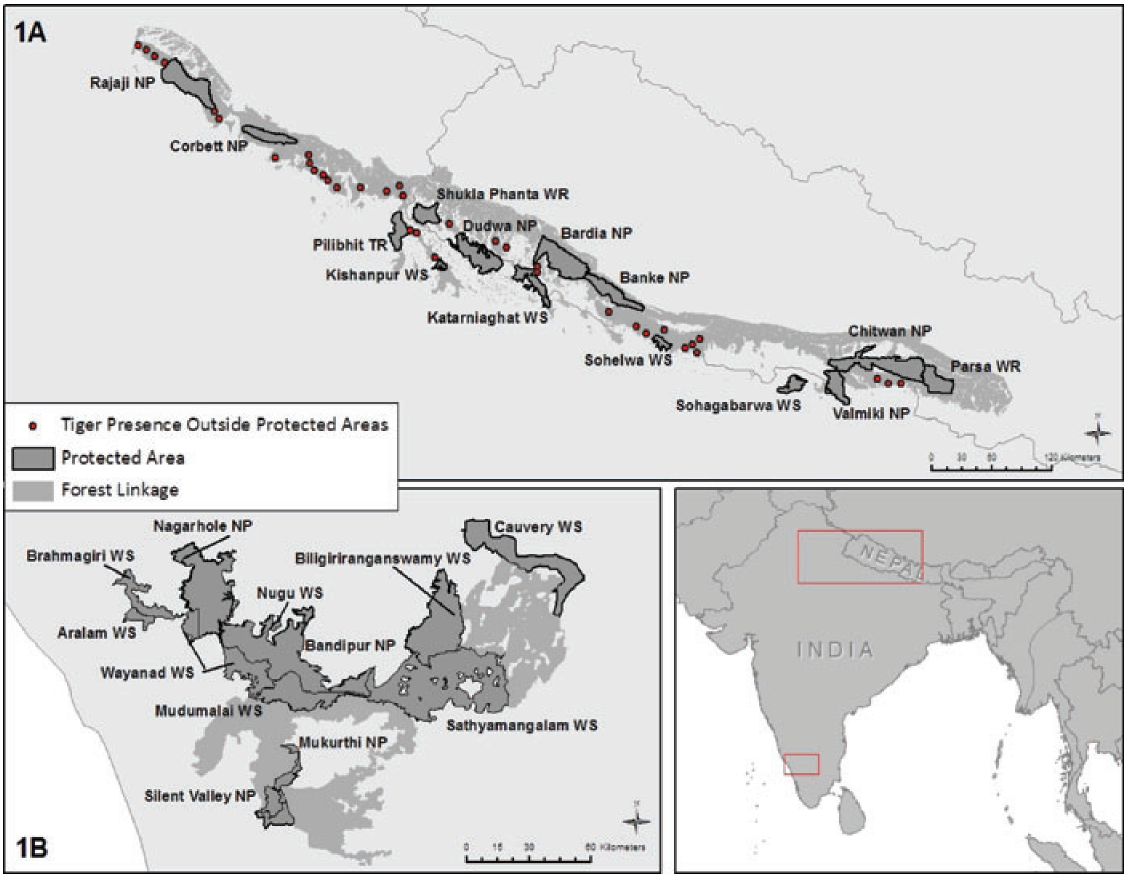

Figure 3 The Terai Arc Landscape, showing protected areas and habitat linkages (A). Tiger populations in Sukla Phanta and Bardia survived heavy poaching during a period of civil unrest because both reserves have habitat linkages to reserves in India and tigers use these corridors. Figure 3B shows the location of Nagarahole National Park in relation to the other protected areas and forest linkages in the landscape that contained tigers. The tiger population in Nagarahole underwent a threefold fluctuation with considerable turnover of individuals due to "mortality" and immigration and emigration over a 10-year period of intense monitoring (see Karanth *et al.* 2006).

landscapes in which tiger reserves are embedded, resulting in rapid isolation of reserves (DeFries *et al.* 2005).

By definition and delineation criteria, the core areas embedded within respective Tiger Conservation Landscapes are connected by habitat that can facilitate tiger dispersal between them (Sanderson *et al.* 2006). However, a scenario projecting habitat loss in Tiger Conservation Landscapes shows a possible 43% reduction during the next decade (Wikramanayake *et al.* 2010b). But a second, restoration-based projection shows there is also potential to improve connectivity within landscapes, and even link adjacent Tiger Conservation Landscapes. In the latter scenario, the joined Landscapes could represent >1.5 million km^2 of tiger habitat, increasing the range to 10% of its historical extent, from 7% in 2006. Improving connectivity within and between landscapes will also provide a hedge against the impacts of climate change, when habitat and climatic shifts could result in corresponding shifts by other biodiversity and by people.

The Asian Development Bank (ADB & ADBI 2009) estimates that about $750 billion per year will be invested over the next decade in new infrastructure projects in the Asia-Pacific region. Many are roads and highways that will traverse reserves. Failure to engage immediately, during project conceptualization and design phases, to mitigate impacts will undermine tiger conservation efforts and further isolate reserves. The 6% solution advocated by Walston *et al.* (2010) runs the danger that development planners will construe it to be a scientific position on the spatial requirements for tiger conservation, and ignore efforts to maintain habitat connectivity, and further isolate reserves. To prevent a perverse interpretation, conservationists must strongly advocate for and secure existing corridors now so connectivity is not lost.

Tigers recover rapidly with protection and sufficient prey and water, but lost tiger habitat will be much more difficult to reclaim and restore, especially in corridors.

In the Terai Arc Landscape, for example, a critical corridor across the Gola River maintained connectivity for elephant and tiger movement. Despite early recognition of this vital corridor (Johnsingh *et al.* 2004), it was severed in 2 years by construction of an oil depot. Conservation groups are now in litigation to remove the depot. Timely action could have avoided this situation.

Policy implications for a landscape-based conservation strategy

The St. Petersburg Declaration recognizes the important ecological role of tigers as an umbrella species for conservation of other biodiversity and the co-benefits tiger habitat conservation offers for maintaining vital ecosystem services including carbon sequestration and water provisioning. Most major donor agencies lack a mandate to finance tiger protection and habitat restoration, especially in reserves and parks, but do recognize their mandate to improve livelihoods of local communities. Promoting sustainable forest and natural resource management in tiger landscapes can both address livelihoods and protect tigers, which are a barometer indicating ecosystem health. Many of the large, intact tiger landscapes also cover important watersheds of major Asian river systems that sustain important ecological services such as water provisioning. The St. Petersburg Declaration recognizes these relationships and stresses the importance of including co-benefits for local communities in tiger conservation plans. Thus, conservation organizations must form alliances and partnerships to strategically channel funds invested by these donors for better landscape management that benefits both people and tigers.

Tiger landscapes have almost 3.5 times the density of carbon per hectare versus all land cover designations occurring outside tiger landscapes (WWF unpublished analysis 2010, based on Ruesch & Gibbs 2008). With carbon trading gaining momentum, range countries that conserve large forested landscapes for tigers could also earn carbon credits (see Linkie & Christie 2007; Venter *et al.* 2009). The St. Petersburg Declaration calls for using mechanisms such as REDD+ to protect tiger habitat, which will sustain ecosystem services and contribute to climate stability. "Premium" carbon credits based on tiger occupancy could augment carbon payment schemes to finance conservation in range countries and benefit many endangered smaller vertebrates, invertebrates, and plants besides the large mammal species which the premium credits will initially target.

To conserve tigers within and beyond reserve boundaries, tigers must be worth more to local communities alive than dead. Conservation interventions in the next decade must include finding new ways of channeling revenues to communities from wildlife tourism, promoting community-forest management in corridors and buffer zones, earning forest carbon credits, and transfer mechanisms from infrastructure projects that generate annual revenues (Quintero *et al.* 2010). These models apply not just to tiger conservation, but to the conservation of other wide-ranging species in habitats threatened with fragmentation and loss by fast-paced development in other parts of the world. Several working models exist in Nepal and other range states (Dinerstein *et al.* 1999). Mainstreaming wildlife conservation into the development agenda must shift from a slogan to well-funded efforts to protect core areas and larger landscapes, a challenging task that will require innovation from conservationists through arrangements that benefit the rural communities living in these landscapes.

The St. Petersburg International Tiger Forum was the first global summit about saving a nonhuman species. For the endangered tiger—and for all of the species and ecosystem functions that fall under its umbrella—the summit may serve as the last substantive opportunity to restore the world's most iconic carnivore. We must use the political will from the summit to achieve conservation at scales necessary for long-term persistence of tigers, and to deliver other ecological outputs that only large landscapes can provide. The intersection of the tiger's ecological needs and rapid land-use changes across the range demand it as a matter of urgency.

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