CHAPTER

9

Setting Priorities for Tiger Conservation: 2005–2015

Eric W. Sanderson[1], Jessica Forrest[1], Colby Loucks[2], Joshua Ginsberg[1], Eric Dinerstein[2], John Seidensticker[3], Peter Leimgruber[4], Melissa Songer[4], Andrea Heydlauff[1], Timothy O'Brien[1], Gosia Bryja[1], Sybille Klenzendorf[2], and Eric Wikramanayake[2]

[1]Wildlife Conservation Society, Bronx, New York, USA

[2]World Wildlife Fund, Washington, DC, USA

[3]Smithsonian's National Zoological Park, Washington, DC, USA

[4]Smithsonian's National Zoological Park, Front Royal, Virginia, USA

OUTLINE

INTRODUCTION

Tigers sit at the feet of Buddha, are mounts to Shiva and Parvati, punish sinners for Allah, and convey both the yin and the yang of Chinese traditions [1]. They are important to cultures not only in Asia, but also throughout the world. However, tigers are increasingly disappearing from the ecosystems where they evolved and the nation states in which they live. Their vast range in Asia has been reduced to a small number of isolated populations, they are hunted intensively for the trade in tiger parts, and the prey on which they depend has been reduced throughout much of their range [2]. The dramatic declines in tiger populations over the last 150 years have made Asia's largest feline predator an endangered species [3].

Many different people and organizations are striving to reverse these trends. Species conservation planning is the science and art of allocating conservation efforts to those priority places and actions that will provide the greatest returns for species survival and ecological function in the wild. Species conservation planning requires clearly stated goals, an assessment of the current status of the species, a directed process for selecting where to work, and a mechanism to measure success [4]. But plans are only as good as the implementation that follows, which is why this chapter includes recommendation on achieving priorities for tiger conservation.

Tiger conservation has long been at the forefront of species conservation planning. With the publication in 1997 of *A Framework for Identifying High Priority Areas and Actions for the Conservation of Tigers in the Wild* [5] (hereafter TCU 1.0), conservation scientists and practitioners welcomed a new vision for saving tigers in the wild. TCU 1.0 shifted the way we conceptualized tiger conservation, from tigers as a single undifferentiated and declining population (or populations of subspecies), to geographically and ecologically distinct groups (both populations and subpopulations) of tigers which exist in different regions and habitat types across Asia, are largely disconnected from one and another, and have differing population trajectories. It established the conservation of 'tigerness' as a primary goal; that is, not only conserving demographically viable numbers of tigers, but also conserving the suite of adaptations in which tigers have evolved, across the range of ecosystems, prey assemblages, and species interactions where they are found. Above all, TCU 1.0 indicated, through a series of policy-friendly maps, where wild tigers still existed, where tigers could live but had been extirpated, and where more information was required to determine the status of tigers.

Over a decade has passed since the publication of TCU 1.0, and, in the intervening time, several important factors have changed which justified a revised set of priorities for tiger conservation. First, the situation of tigers has changed, both in terms of their conservation and our knowledge of their biology. Many of the places, which were poorly understood in the mid-1990s, have now been surveyed. We have a greater appreciation of the role of prey communities in sustaining tiger populations [6]. We know more about how tiger densities vary across their range [7] and new methods for estimating their abundance have developed so that we can now regularly monitor population trends [8]. In spite of better data, many of the new findings remain disjointed, lacking a unified framework that would allow policy-makers to assess clearly the situation of tigers across the range.

Furthermore, the field of species conservation planning as a whole has changed over the past decade. There is growing consensus behind the idea that saving a species means planning for representative, redundant, and resilient populations across the historical range of a species [9,10], an idea that has its roots in TCU 1.0. [11]. For tigers, this goal means that we seek to sustain them in all major habitat types and regions (representation); secure multiple instances of those populations to avoid catastrophic loss (redundancy); and restore populations large enough to be both ecologically functional and able to rebound after disturbance (resiliency).

Species conservation planning has also changed in terms of the data and methods available. Spatially explicit datasets (i.e. maps) are more accessible and are of higher accuracy than those available 10 years ago, and the computational tools—such as geographic information systems (GIS) and landscape modeling—are much improved, allowing for more sophisticated analyses to be made. The result is an improvement in the transparency and rigor in identifying 'Tiger Conservation Landscapes (TCLs),' and these landscapes can now be continuously updated over time with minimal additional effort.

This chapter summarizes the essential findings of *Setting Priorities for the Conservation and Recovery of Wild Tigers: 2005–2015* (hereafter TCL 2.0; the shift from 'Tiger Conservation Units' to 'Tiger Conservation Landscapes' reflects one of the main changes) [12]. We outline the datasets and methods used, present the essential results, and set measurable conservation goals against which future efforts—successful or otherwise—can be measured. The guiding principles of TCL 2.0 are:

1. ensuring that the concept of 'tigerness' (representation of ecological distinctions of tigers across different habitats) stays central to the prioritization of conservation investment across the range;
2. securing known breeding populations as the highest priority, because they will be the source populations for the future recovery of tigers;
3. identifying zones of high connectivity between and among TCLs so that in the future we can re-create natural landscapes that protect tigers and other species;
4. planning across the tiger's entire historical range for the next one hundred years, while recognizing that near-term efforts will focus in the current range; and
5. using methods and datasets that are rigorous, transparent, and up-to-date, with the capacity to update them in the future as new information becomes available.

Taken together, these principles or building blocks enable us to begin thinking about the concept of meta-TCLs, large areas of connected habitat spanning vast areas of the tiger's range. Over the long-term, we think it is easily possible for Asia to recover 100,000 tigers in the wild by the year 2100, starting with the landscapes we define here.

METHODS

Study Area

To define the approximate historical range of tigers in 1850 we digitized and modified a map of historic tiger distribution from Nowell and Jackson, incorporating cited accounts [13].

Within this study extent, we defined major habitat types based on the World Wildlife Fund's terrestrial ecosystem mapping of the world [14] and the following regions for representation: Bali and Java, Central Asia, China–Korea, Indian Subcontinent, Indochina, Peninsular Malaysia, Russian Far East, Sumatra. We created a mask to show all the areas where tigers are considered extirpated in Central Asia, Bali, Java, all of China south of Heilongjiang on the border with Russia, and parts of interior Russia and Mongolia (Fig. 9.1).

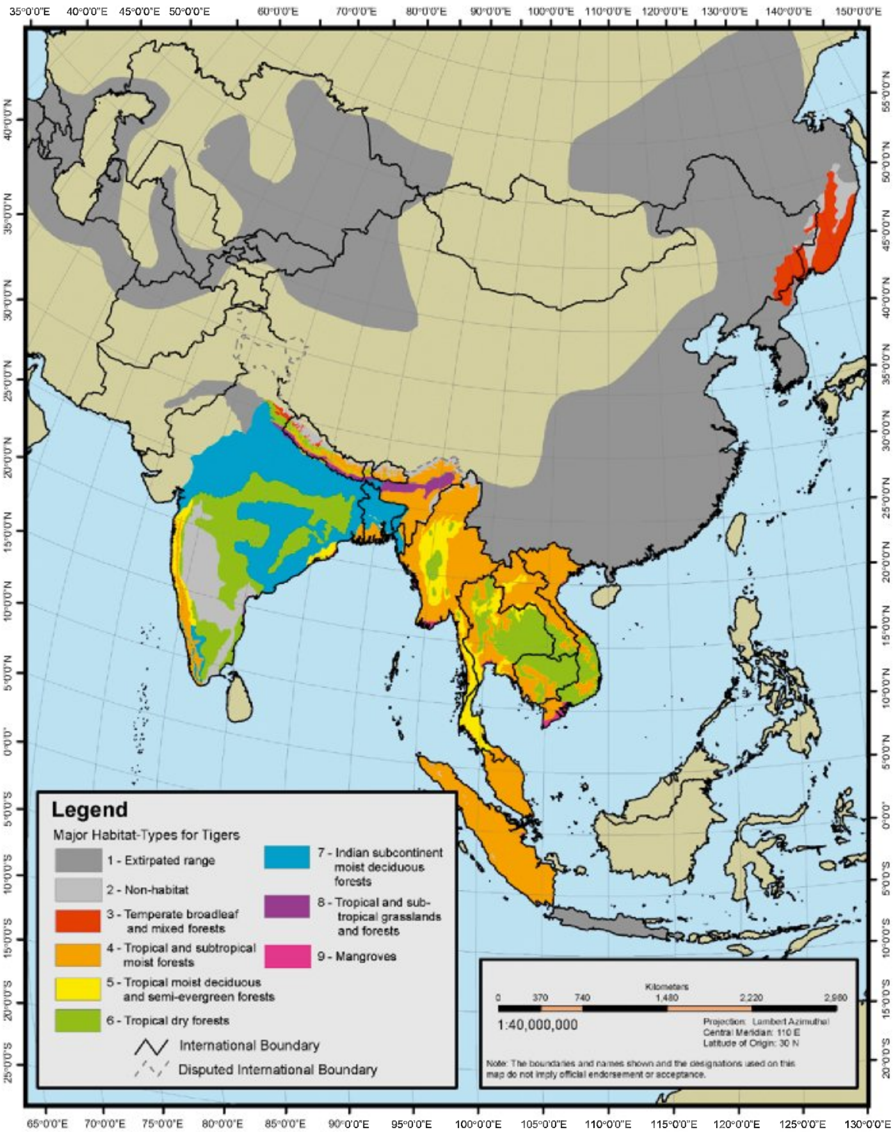

FIGURE 9.1 Historical range of tigers, circa 1850, showing the potential distribution of major habitat types. Tiger populations should be conserved in all major habitat types so that 'tigerness' in its many varieties may be conserved.

Tiger Observations

We collected a database of tiger observations by sending an email questionnaire to 273 individuals working on tiger research or conservation efforts. We asked respondents to provide the location, and the days of active search, for any search that had been made for tigers between 1995 and 2005. For any successful search, we also asked for the method of observation (e.g., camera-trap, radio collar, tracks or sign, tiger mortality, etc.), evidence of breeding (e.g., cubs or breeding den), and estimates of the precision of the location. We asked respondents to lump all observations made within 20km of each other and within a 3-month period. We also searched the published literature and unpublished papers and reports, including all reports in the files of the Wildlife Conservation Society, World Wildlife Fund–US, and the Save the Tiger Fund from 1995 to 2005. We complemented this literature survey with additional data supplied by the tiger expert community during mid-project reviews. In some cases, experts provided data about the locations of tigers within specific areas, usually protected areas, but without point specific localities. These became 'tiger polygons.' In subsequent analysis, we represented all tiger point locations with a buffer scaled to habitat-specific home range sizes and used the 'tiger polygons' as they were.

Tiger Land Cover Data

We compiled a range-wide database of tiger habitat based on existing land cover datasets for the region. Where possible, we used higher resolution (30m) datasets based on analysis of Landsat Thematic Mapper imagery. These included the Russian Far East; Sumatra; the central highlands of Vietnam; and Lao PDR, the Mekong River basin, Myanmar, and the Terai Arc in Nepal [12], covering approximately 11% of the historic tiger range. For all other areas we relied on the Global Land Cover Characterization (GLCC) map from 1992 (1km resolution) [15], supplemented in selected localities with the MODIS Global Land Cover from 2000 [16]. The GLCC dataset was preferred in most cases because it more closely matched the high-resolution Landsat datasets. We only used datasets with an average classification accuracy greater than 77%.

From this land cover database, we defined 'structural land cover' for tigers as all cover classes that could potentially provide cover, prey, and breeding areas (Fig. 9.2). We classified all areas above 3350m, montane grasslands and scrub above 2000m, and human-dominated land cover types (including urban areas and agriculture) as 'non-habitat.' A filter was applied across the structural land cover map to exclude patches less than 5 km^2, thus creating a minimum mapping unit of 5 km^2.

Human Influence Index

Comparison of the tiger observation database and the structural land cover indicated that tiger habitat was overestimated in the satellite imagery. We therefore incorporated a measure of human influence to compensate for the 'empty forest' phenomenon [17]. To avoid overestimating tiger habitat, we incorporated thresholds based on the Human Influence Index (HII), a precursor to the Human Footprint dataset [18]. The HII is composed of the weighted

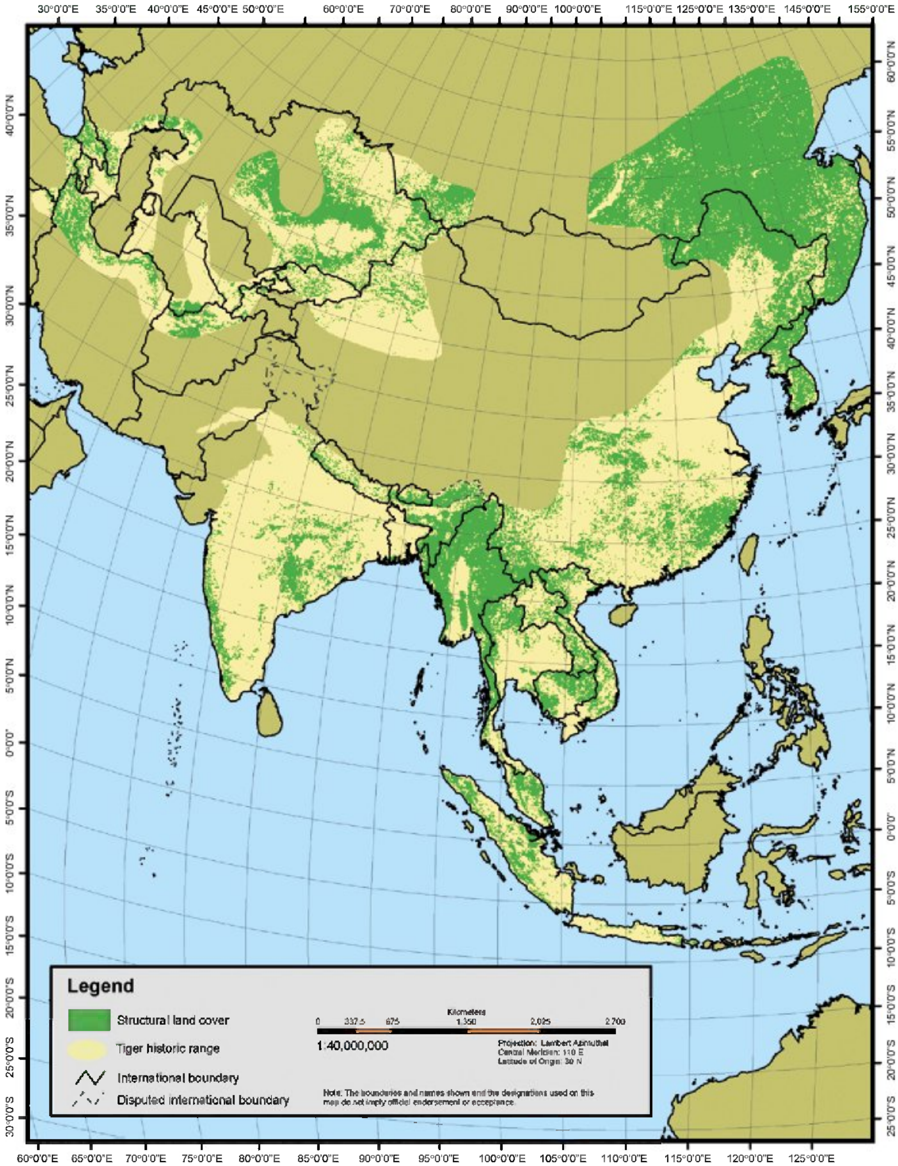

FIGURE 9.2 Structural land cover, based on satellite-derived natural land cover types appropriate for tigers (circa 2000–2005), and tiger observation localities between 1995 and 2005.

sum of human population, land use, access, and power infrastructure datasets and scores each 1 km^2 pixel throughout the globe on a scale of 1–72, with 72 indicating highest levels of human influence or pressure.

In order to determine the HII threshold important to tigers, we compared the average human influence values of points where tigers have been found ('presences'), and points where tigers have not been found ('putative absences'), to the overall distribution of human influence within the tiger's current range. If tigers are present more often at a given human influence value than expected by random, we found a positive, non-zero deviation from the overall human influence distribution; if tigers were found less often than expected by random, there was a negative, non-zero deviation. A similar analysis was conducted for the absence data. From this analysis we developed a minimum threshold to define 'potential effective habitat' from the structural land cover map. A range of HII values was tested through sensitivity analysis [12].

Habitat-Specific Minimum Patch Sizes and Connectivity Rule

The map of effective potential tiger habitat shows available habitat for tigers across the range. Tigers generally require large blocks of habitat and are unable to use small patches that are not closely connected to larger areas. What constitutes a connected area is less clear, so we used a conservative approach to map connectivity according to the presumed dispersal capability of tigers.

We used information on tiger densities to determine minimum core area and stepping stone size requirements for each habitat type [7, 19]. Habitat areas were represented by WWF ecoregions [14] that were further grouped into 'density regions' according to their characteristics for supporting similar densities of tigers. We defined a minimum size for a 'core' habitat block for a TCL to be 'big enough for five over 1 year old tigers', which varies between 30 and 625 km^2 depending on these different 'density regions' [12]. We set the minimum 'stepping stone' habitat patch to be 10% of the 'core' habitat block, with a range between 5 and 63 km^2.

To simulate habitat connectivity, we assigned all habitat and stepping stones within 4 km of one another and meeting the minimum size requirements for that habitat-type to a unique habitat group. On rare occasions where a wide river exceeding 1 km intersected a polygon (habitat patch group), the landscape was split into two distinct areas. Detailed research on tiger dispersal movements is largely lacking; 4 km is considered a conservative estimate of a tiger's ability to cross human-dominated areas (Seidensticker, Dinerstein, personal communication).

Tiger Conservation Landscape Delineation

We used these datasets to delineate TCLs across the tiger's historical range. TCLs are the minimum unit for all further analysis. We created the following definition:

> A ***Tiger Conservation Landscape (TCL)*** is a block or cluster of blocks of 'potential effective habitat' within 4 km of each other, meeting a minimum, habitat-specific size threshold, where tigers have been confirmed to occur during the last 10 years and are not known to have been extirpated since the last observation.

Working off this definition, we used the same size and connectivity rules to define:

- ***Restoration Landscapes***: Large areas of structural land cover under low human influence where survey efforts since 1995 have not revealed evidence of tigers.
- ***Survey Landscapes***: Large areas of structural land cover under low human influence where tiger status is unknown. To our knowledge, these areas have not been surveyed since 1995.

- ***Fragments with Tigers***: Small areas of structural land cover of low to high human influence that show evidence of tigers. These areas are too small to meet the minimum area requirement to be TCLs, but are important nonetheless for supporting the tigers that live there.

We classified effective potential habitat under the extirpated mask ***Extirpated Landscapes*** using the same size-threshold and connectivity rules. Extirpated Landscapes include large areas of habitat in China and Central Asia, and small habitat blocks on the island of Java. Extirpation in some of these areas is recent, in some cases within the last 20–50 years.

All remaining areas of both the current and extirpated portions of the tiger's range are categorized as ***Lost Habitat***. These areas do not meet the criteria necessary to be a Landscape or a Fragment with Tigers. Included in this category are areas either lacking structural land cover for tigers, areas with too much human influence, or blocks too small and disconnected to support tigers.

Automation

The delineation of TCLs and other landscape types was implemented using Arc Macro Language scripts for ArcGIS 9 (Environmental Research Systems Institute, Redlands, CA). The entire process runs in approximately 30 minutes.

Taxonomy for Tiger Conservation Landscapes

To describe priorities for tiger conservation, we first defined a 'success' for tiger conservation as a known and secured breeding population of tigers in an area large enough for a substantive population (>100 tigers). Therefore, a 'successful' landscape (a Class I TCL) should possess a known breeding population with a sufficient prey base, have sufficient area (scaled by habitat type), and reduced level of threats. In general, as tigers are a conservation-dependent species, conservation measures need to be in place, both locally and nationally, to ensure long-term survival.

Class definitions were conditional in the sense that all conditions must be met for a landscape to be assigned to Class I.

'Lower'-class TCLs are those that have the potential to reach Class I status, but need more conservation effort to reach that status. Class II TCLs have the potential to secure a breeding population through conservation efforts in the next 10 years. Class II TCLs will typically be places where there is sufficient habitat, but where threats are reducing tiger populations, prey populations, or both; such that conservation measures, if implemented with vigor and dedication, could protect populations and allow the TCL to recover to Class I status over the next 10 years.

Class III TCLs require even more effort and longer time horizons, perhaps because there is insufficient habitat, the prey bases are too diminished to recover within a decade, or there is a lack of commitment to tiger conservation by local people and government in that TCL. Thus, though important, their conservation will likely take a sustained effort of more than 10 years to rebuild habitat and connectivity to the required state.

Finally, there will be TCLs where we lack enough information to credibly distinguish what class of TCL they are; these areas with insufficient information are marked as Class IV. Providing the required information could immediately reclassify these TCLs into a higher class type. Table 9.1 summarizes the definitions of the different TCL classes if adequate data on all criteria were available.

TABLE 9.1 Definitions for TCL classes (I, II, III, and IV)

	Population status	Prey population	Habitat area	Threats to tigers	Conservation measures
Class I TCL	Scientifically estimated populations ≥100 tigers, and evidence of breeding.	Evidence of stable and diverse prey populations.	Enough inter-connected habitat for 100 female tiger home range equivalents, scaled by habitat type.	Little to none, either because of lack of threat or conservation.	Effective conservation measures in place, active enforcement, likely some protection.
Class II TCL	Populations ≥50 tigers.	A basis for prey populations to rise, but not currently sufficient.	Enough inter-connected habitat for 50 tiger home range equivalents.	Threats potentially can be mitigated in the next 10 years.	Basis for conservation in place, but insufficient effort.
Class III TCL	Some tigers.	Prey non-existent or so low that 10 years or more is required for recovery.	Less than 50 tiger home range equivalents of habitat.	Threats exist and probably cannot be sufficiently mitigated in the next 10 years.	Need to build the basis (legal, actual) for conservation.
Class IV TCL	Insufficient information on three or more conditions.				

Prioritization of Tiger Conservation Landscapes

Finally, to incorporate the classified TCLs into a system of prioritized representative, redundant, and resilient units for conservation, we considered each TCL within a system of major habitat types.

Given the dramatic reductions in tiger populations and range over the last 150 years, all 'successes' (Class I TCL) are valuable, regardless of their location. Thus all Class I TCLs were considered 'Global Priorities' for tiger conservation. In major habitat types without Class I TCLs, the largest Class II TCL (or Class III TCL if no Class II TCLs were found) was assigned 'Global Priority.' This step ensures that there is at least one 'Global Priority' representative in all major habitat types.

Within the two most extensive major habitat types (tropical moist and tropical dry forest), which contain more than 75% of the TCLs, we assigned additional Class II TCLs by size so that there were at least three 'Global Priority' TCLs in each bioregion. This step provides for redundancy wherever possible within the major habitat types.

All remaining Class II TCLs were assigned 'Regional Priority' status, and Class III TCLs were assigned to 'Regional Priority' in parallel fashion to the 'Global Priority' rules above.

All remaining Class III TCLs were assigned to 'Long-term Priority.' All Class IV TCLs were assigned to 'Insufficient Information to Prioritize.' Some of these TCLs might change priority status dramatically if more information were available.

We also prioritized the top 20% (by area) of the Survey and Restoration Landscapes within each bioregion.

RESULTS

Status of Tiger Range

According to our estimates, in 2005 tigers occupied only 7.1% of their historical range (Table 9.2). This represents a 92.9% range collapse over the last 150 years.

We obtained this estimate by progressively analyzing the area within the tiger's historical range, which we estimate once covered over 16.6 million km^2. Over 57% of the range has already been converted to urban areas, cropland or settlements unsuitable for tigers. Tigers have been entirely extirpated from more than 30% of their range, notably in Central Asia and most of China, and all of Bali and Java.

Analysis of tiger presence and absence data indicated a transition in expected presence of tigers at Human Influence Index (HII) value 16. Below HII 16, tigers can be found more often than would be expected by random sampling; while at values above HII 16, it is less likely than expected to find them [12]. To create a map of 'effective potential habitat' we excluded areas of structural land cover with HII scores higher than 15. The result is that tigers are excluded from another 9% of the historical range (or 20% of the current structural habitat) due to factors related to human influence, most likely prey depletion and direct killing of tigers. We retained areas with documented evidence of tigers regardless of their HII score.

TABLE 9.2 Status of tiger range, circa 2005

Category of tiger range[a]	Total area (thousand km^2)	Historic range (%)	Remaining structural habitat (%)	TCLs (%)
Tiger Historical Range	16,614	100	-	-
Habitat Lost, through land cover change (no tigers)	(−9,516)	(−57)	-	-
Structural Habitat remaining	7,098	43	100	-
Extirpated Habitat (no tigers)	(−4,959)	(−30)	(−70)	-
Excluded Habitat (no tigers)	(−1,424)	(−9)	(−20)	-
Tiger Conservation Landscapes[b]	1,190	7	15	100
Class I	891	5	11	75
Class II	122	1	1	10
Class III	73	0.4	1	6
Class IV	103	1	1	9
Small Fragments with Tigers	17	0.1	0.2	-
Survey Landscapes	431	3	5	-
Restoration Landscapes[c]	4,849	29	61	-

[a] See text for definition of range categories.
[b] Tiger Conservation Landscapes can include some 'Excluded' habitat because of the dispersal rules.
[c] Restoration Landscapes are identified across the entire range, including areas where tigers are currently extirpated (e.g. Central Asia, Java, Bali, parts of China and Russia).

Finally, within the remaining habitat—which appears structurally sound from satellite imagery and has human influence scores below the measured threshold—only 15% of the area can be categorized as a TCL due to the known presence of tigers. We gathered over 2,700 point locations where surveys for tigers have been carried out over the last 10 years; 91% of these locations indicated evidence of tiger presence. Only 8% of the points recorded evidence of tiger breeding. Sixteen percent of the observations had no data regarding observation type. Of the remaining points, tiger tracks (65%), photographs from camera-traps (42%), radio telemetry (21%), and scats (19%) were the most frequently recorded methods for making tiger observations (note: often multiple observation techniques were used, so these percentages total more than 100%). These points were supplemented with more than 300 areas (mainly protected areas and reserves) of documented tiger presence over the last decade based on a survey of the available literature, creating a database of over 3,100 survey locations.

Comparison to TCU 1.0

Direct comparison to TCU 1.0 is problematic because of the differences in methods and quality of data sources. Simple overlay analysis indicates that tiger habitat (as mapped in TCU 1.0) has shrunk by as much as 41% since 1995, which is likely an overestimate given the differences in precision between the two exercises. However, in some areas, this comparison may be appropriate. Deforestation and degradation rates in Southeast Asia over the same period have ranged from 1.13 to 5.9% per annum, which when compounded result in losses of structural habitat of 10% generally, and up to 45% in some parts of the range since 1995 [20]. Deforestation hotspots occur in some formerly prime tiger areas like Sumatra, Malaysia, Bangladesh and central Myanmar.

Tiger Conservation Landscapes

We identified 76 TCLs, 491 Survey Landscapes, 34 Restoration Landscapes, and 543 Small Fragments with Tigers in the current tiger range (Figs 9.3 and 9.4). In the extirpated range of China, Central Asia, and Java, 427 Restoration Landscapes were delineated, 14 of which are believed to have been inhabited by tigers within the last 30 years.

Tiger Conservation Landscapes are distributed across 10 different biomes, ranging from the boreal forests of Russia to tropical and subtropical grasslands and broadleaf forests in India and Southeast Asia (Table 9.3). Of all the habitat types, the majority of existing TCLs are found in tropical moist broadleaf forests, followed by temperate broadleaf and mixed forests (mainly within the Russian Far East), followed by tropical dry forests.

Regionally, we found that the largest area of effective potential habitat remains in the Russian Far East, consisting of over 2 million km^2, though much of this is in relatively low quality boreal forest. The smallest amount of remaining effective potential habitat as a percentage of total habitat is in the Indian Subcontinent, where all but 300,000 km^2 (or 11% of total habitat) excludes tigers. Interestingly, the places with the most remaining unoccupied effective potential habitat exist in places where tigers have been extirpated. For example, about 25% of the now extirpated geographic regions of China and Central Asia have structural land cover below the human influence threshold. This indicates that there may be the potential for future reintroduction in these areas, if the threats are alleviated and conservation measures are instituted.

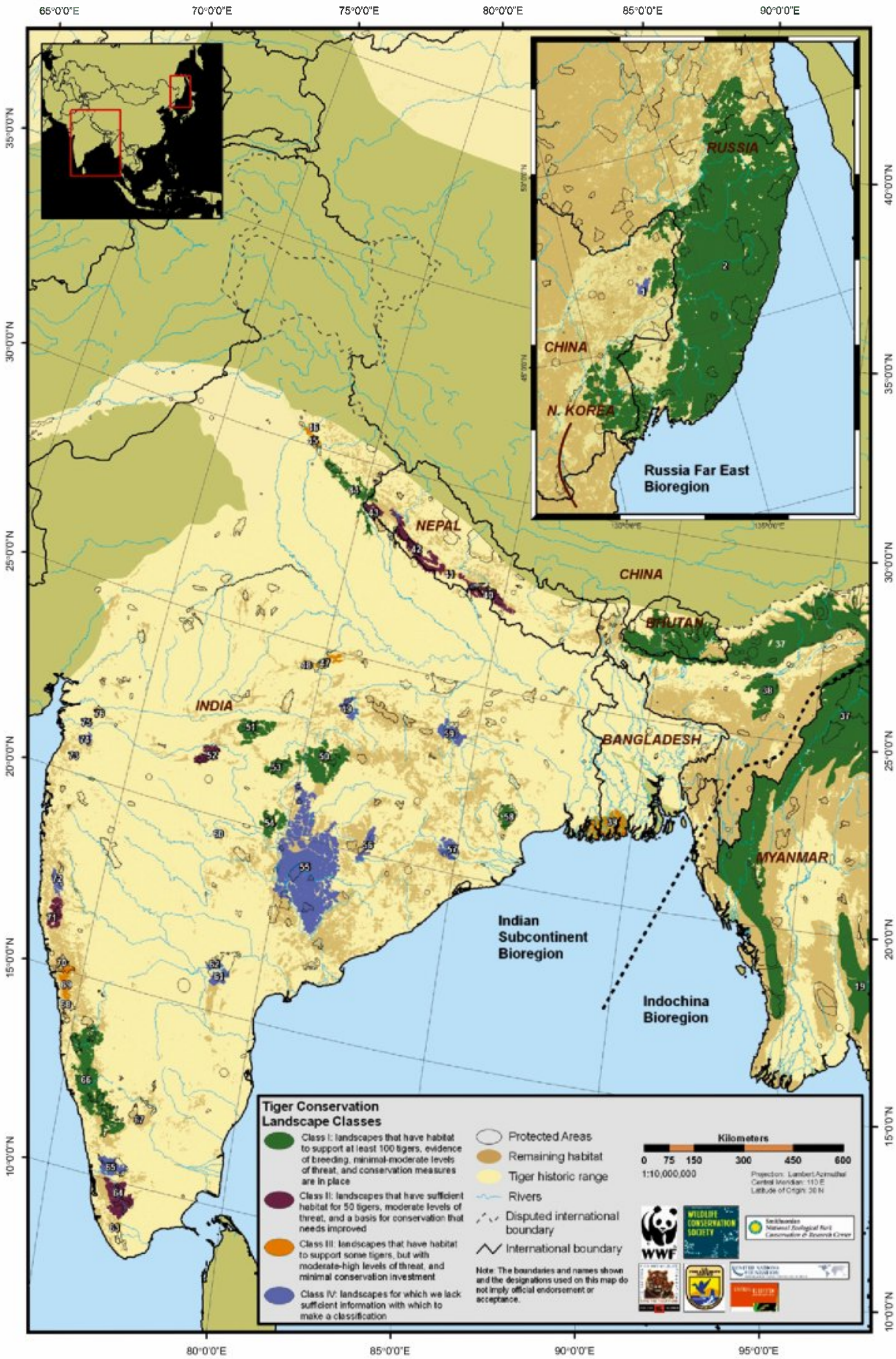

FIGURE 9.3 Tiger Conservation Landscapes (TCLs) Indian Subcontinent and Russia Far East/China bioregions. Numbers refer to specific TCLs as listed in Sanderson et al. [12].

FIGURE 9.4 Tiger Conservation Landscapes (TCLs) in the Southeast Asia and Indochina bioregions. Numbers refer to specific TCLs as listed in Sanderson et al. [12].

TABLE 9.3 Global priority Tiger Conservation Landscapes

Name of landscape	Total TCL area (km^2)	Class designation[a]	Tiger range nations	Major habitat types[b]
Russian Far East – China	269,983	I	Russia, China	TeBM, BF/Ta, FGS
Northern Forest Complex—Namdapha—Royal Manas	237,820	I	India, Myanmar Bhutan	TMF, TCF, TeBM, TeCF, TGS, MGS
Tenasserims	162,726	I	Myanmar, Thailand	TMF, TDF
Southern-Central Annamites	61,252	I	Cambodia, Lao, Vietnam	TMF, TDF
Taman Negara—Belum	49,181	I	Malaysia, Thailand	TMF
Kerinci Seblat	28,162	I	Indonesia	TMF, TCF
Cambodian Northern Plains	26,835	II	Cambodia, Lao, Thailand	TDF
Western Ghats—Bandipur—Khudrenukh—Bhadra	18,973	I	India	TMF, TDF
Nam Et Phou Loey	17,866	I	Lao, Vietnam	TMF
Kanha—Phen	10,598	I	India	TMF
Kaziranga—Garampani	7,514	I	India	TMF
Bukit Tigapuluh Landscape	7,106	I	Indonesia	TMF
Corbett—Sonanadi (part of Terai Arc)	5,996	I	India, Nepal	TMF, TCF, TGS
Sundarbans	5,304	I (III)	Bangladesh, India	Mangroves
Pachmarhi—Satpur— Bori	4,924	I	India	TMF
Thap Lan—Pang Sida	4,445	II	Thailand	TDF
Andhari—Tadoba	3,680	I	India	TDF
Pench	2,918	I	India	TMF, TDF
Simlipal	2,412	I	India	TMF, TDF
Melghat	2,398	II	India	TDF

[a]Class designations are explained in the text.
[b]TMB = Tropical and Subtropical Moist Broadleaf Forests, TDF = Tropical and Subtropical Dry Broadleaf Forests, TCF = Tropical and Subtropical Coniferous Forests, TeBM = Temperate Broadleaf and Mixed Forests, TeCF = Temperate Conifer Forests, BF/Ta = Boreal Forests/Taiga, TGS = Tropical and Subtropical Grasslands, Savannas and Shrublands, FGS = Flooded Grasslands and Savannas, MGS = Montane Grasslands and Shrublands.

Classification and Prioritization of Tiger Conservation Landscapes

Classes provide measures on an absolute scale of the current quality of tiger conservation (Table 9.1). Of the 76 TCLs, 16 were designated Class I, 15 as Class II, 23 as Class III, and 22 as Class IV (Figs 9.3 and 9.4). While only 21% of the TCLs were placed in Class I, the greater average size of these areas means that over 77% of the total area delineated as TCLs is categorized as Class I—breeding tiger populations in large areas with some conservation activity and relatively lower threats. In other words, there are a small number of large TCLs which are the last 'strongholds' of tiger conservation.

Class II TCLs (areas that could recover within the next decade given necessary investment) make up approximately 10% of TCLs by area. The Class III TCLs will take longer to recover—they comprise 4% of the total TCL area. Nine percent of the overall TCL land area requires more information (classified as Class IV TCLs).

Priorities represent relative measures of quality and incorporate explicitly representation—they tell us where the best-conserved TCLs are within different regions and biomes. Twenty TCLs were prioritized as 'Global Priorities for Tiger Conservation' (Table 9.2). This set represents all the major biomes and bioregions where tigers occur. All but four of these areas are Class I TCLs. To ensure representation, we 'promoted' the Sundarbans, a Class III TCL, to the Global Priority category to represent Mangrove habitat. To assure redundancy in Tropical Dry Forest, we also assigned Global Priority status to Melghat in the Indian Subcontinent and to Cambodian Northern Plains and Thap-Lan-Pang Sida in Indochina.

Thirteen TCLs were identified as 'Regional Priorities for Tiger Conservation.' These areas represent four tropical biome types and therefore only occur in the tropical bioregions of the Indian Subcontinent, Indochina, and Sumatra. The majority of these are Class II TCLs. Panna East from the Indian Subcontinent was assigned Global Priority status to meet the redundancy criteria in Tropical Dry Forests. Insufficient TCLs were identified in other biomes to provide 'regional' priorities across the range.

Twenty-one TCLs were identified as 'Long-term Priorities for Tiger Conservation' and 22 TCLs lacked sufficient information to prioritize. Adding conservation and threats information for these Class IV TCLs would enable them to be classified and prioritized with the others.

There are two areas, representing no less than seven biomes between them, which are critically important for global tiger conservation: the **Russian Far East** (Russia and China) and the **Northern Forest Complex/Namdapha/Royal Manas** (Myanmar, India, China, and Thailand). When combined with Corbett/Sonanadi (India), Tenasserims (Thailand and Myanmar), Southern Annamites (Vietnam, Lao PDR and Cambodia), and the Sundarbans (India and Bangladesh), these TCLs capture the largest areas of habitat within all the major biomes for tigers across their mainland Asia range. The two Global Priority TCLs on Sumatra are Kerinci Seblat and Bukit Tigapuluh. All of these areas have breeding populations and some conservation measures in place and should be considered as the highest priority places in the world for conservation of extant tiger populations.

Within the current range, we identified three priority restoration landscapes in the Indian subcontinent, five in Indochina, and two in Southeast Asia. There were no Restoration Landscapes in the Russia Far East bioregion. Other restoration areas, as noted previously, were identified in the 'extirpated' part of the range. In comparison to the Restoration Landscapes, there were many more Survey Landscapes throughout the tiger's range. Many of these areas are small habitat fragments close to TCLs that could be surveyed as part of on-going scientific conservation efforts. We identified 73 survey priorities in the Indian Subcontinent region, 20 survey priorities in the Indochina region, five in Southeast Asia, and two in the Russian Far East.

A full list of classified and prioritized TCLs, Restoration Landscapes, Survey Landscapes and Small Fragments with Tigers is available online at http://www.savethetigerfund.org/.

DISCUSSION

Robust species conservation planning delivers four essential pieces of information to policymakers, conservationists, and the general public: A clear, well-reasoned conservation vision; a systematic and transparent assessment of the current status of the species; a selection of conservation priorities—usually places, but also key threats and conservation measures; and, finally, metrics to measure future success. We believe that TCL 2.0 delivers on all these points.

A Conservation Vision for Tigers

Our vision for the conservation of tigers is rooted in tiger ecology, based on a scientific assessment of their current status, and informed by how valuable tigers are to people and the ecosystems in which they live. Tigers are a long-treasured, nearly ubiquitous part of Asian cultures. Tigers are mythical creatures and gods, characters in stories and fables, have foods and medicines named after them, and are enshrined in the heavens as constellations and on calendars in the zodiac. Tigers are a part of the Koran, the Bhagavad Gita, and the Tao Te Ching. Geographically, even in their current reduced range, the tiger is a part of the natural fauna of 14 nations. Their historical range, from only 150 years ago, doubles the number of modern nations where tigers might once again be found.

In short, the image of tigers, and the very *idea* of tigers, is a defining characteristic of Asia; it is hard to imagine Asia without tigers. By the same token, it is hard to imagine a world without tigers. Tigers are a treasure of the Earth. Witness the list of writers who have written about these great cats: Rumi, Rudyard Kipling, Li Bai, William Blake, Rabindranath Tagore, A.A. Milne. Even if they did not play such an important role in nature, tigers deserve our respect and our efforts to conserve them, if for their cultural value alone [21].

As a part of nature, tigers are important players in the ecosystems where they are found and an essential part of the strategy to save Asian ecosystems. Tigers are apex predators, and their health and prosperity is an indication of the health of the ecosystems on which they depend (see also Chapter 2) [22–24]. These interactions vary in different ecosystems, where tigers may take different prey, have different habitat relationships, and compete with different species. Our goal is to conserve tigers in ecosystems, respecting all the different kinds of interactions tigers have with their environment; thus, our vision is that these interactions be conserved in the 20 'Global Priority' TCLs which we have defined. These TCLs represent the nine major habitat types and six regions where tigers now occur (Table 9.3). These areas total less than a million square kilometers out of a range that was once 16.6 million km^2. By reconnecting these areas and lowering the human influence that excludes tigers from existing forest, we could more than double the area for tigers across Asia over the next century and make space for other species as well. As landscape species, tigers are an essential key to restoring ecosystem services and ensuring long-term maintenance of biodiversity across Asia.

Assessment of Tiger Status

We recognize that a large-scale, bold vision, like the one just outlined, is being described at exactly the same moment that tigers are at the lowest point of their history on Earth.

As Dinerstein et al. [2] noted, tigers are not only endangered, but at crisis point. Our findings show that only 7.1% of the tiger's historical range remains after 150 years of agricultural and industrial development and human population expansion; and that well-conserved tiger populations (with evidence of breeding and adequate areas) are reduced to only 16 places on Earth. We have been able to show that portions of the range have been lost to different causes—to landscape conversion, to poaching and prey reduction, and to loss of connectivity—and that the reductions are large and staggering (Table 9.3).

DIRECTING CONSERVATION ACTION

Recognizing the problem is the necessary first step in solving it. Our analysis clearly points to the most important places on Earth to save tigers and suggests what can be done to conserve them. These landscapes, taken as a set, represent all the range nation states and all the major habitats of tigers (Table 9.2). We know that tigers are a conservation-dependent species, and given continuing pressure from the tiger trade and levels of hunting, even the best-conserved places today will not be sustainable without continuous conservation effort. While continuing to ensure these 'strongholds' for the long-term, we also need to be looking to conserve further tiger areas to ensure replication and help extend the fabric of well-conserved nature over more of Asia. We mapped a total of 76 TCLs; places where, with effort and money, patience and time, tigers could thrive again. Over the longer-term we also show areas where additional information is required (over 490 Survey Landscapes) and designate areas where tigers could be restored (over 460 Restoration Landscapes) when the opportunity arises.

Measures of Success

Finally, our analysis sets measures for evaluating success. The classification system is designed as a measuring stick against which TCLs can be evaluated today and into the future. Ten years from now, how many Class I TCLs will still have enough habitat for breeding populations of 100 tigers? Ten years from now, how many Class II TCLs will have had sufficient conservation efforts to upgrade to Class I levels? Ten years from now, how many Class IV TCLs will still be unknown to the tiger community at large? Future data will answer these questions, against a baseline that is established with this study.

In the meantime, we can continue to use the methods pioneered here to monitor tiger habitat and TCLs. If countries can reduce the levels of human influence in tiger habitats, it may be possible to expand the amount of quality habitat available to tigers. If tigers are found in new areas or reintroduced, we can update the maps we have made by changing the underlying data and re-running the algorithm. TCL 2.0 is a living document that can be used to track the state of tigers.

We accept that good science is necessary but not sufficient for conservation. Science tells us what tigers need and where, as outlined here; however, tiger conservation will require more.

Tiger conservation over the next decade will require building TCLs into the development agendas of range states and into the hearts and minds of people everywhere. We suggest several important areas of funding to define a holistic communication campaign to take these results to the people in Asia and other parts of the world. We need spokespeople at all levels and in all societies, but particularly in Asia, to speak for their natural patrimony, to speak for tigers. We need persistence, generosity, and a willingness to listen, while we push, prod, and kindly but firmly suggest that these results be integrated into regional land use and development plans, into the annual work plans of government, and into the daily consciousness of people everywhere; so that, as Asia's economic tigers continue to rise, wild tigers are not left behind.

ACKNOWLEDGMENTS

This work was funded by Save The Tiger Fund, a partnership between the Exxon/Mobil Foundation; the National Fish and Wildlife Foundation and the Critical Ecosystems Partnership Fund; the United States Fish and Wildlife Service; and the United Nations Foundation. The Wildlife Conservation Society, World Wildlife Fund and the Smithsonian Institution, the Prospect Hill Foundation and the Environmental Systems Research Institute Conservation Program also supported this work. Erika Reuter and Kae Kawanishi provided helpful comments on this chapter.

In addition, we thank the more than 300 scientists, conservationists, land managers, and government officials who contributed information on the current distribution of tigers in the wild. Without their efforts, there would be no tigers in the world.

References

1. Seidensticker J. *Tigers*. Vancouver: Voyageur Press; 1996.
2. Dinerstein E, Loucks C, Wikramanayake E, et al. The fate of wild tigers. *BioScience*. 2007;57:508–514.
3. Cat Specialist Group. *Panthera tigris*. 2008 The IUCN Red List of Threatened Species. <www.iucnredlist.org >; 2008.
4. Groves C. *Drafting a Conservation Blueprint: A Practioner's Guide to Planning for Biodiversity*. Washington, DC: Island Press; 2003.
5. Dinerstein E, Wikramanayake E, Robinson J, et al. *A Framework for Identifying High Priority Areas and Actions for the Conservation of Tigers in the Wild*. New York and Washington, DC: WWF, WCS, NFWS-STF; 1997.
6. Karanth KU, Chundawat RS, Nichol JD, Kumar NS. Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture–recapture sampling. *Animal Conserv*. 2004;7:285–290. Part 3.
7. Carbone C, Christie S, Conforti K, et al. The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conserv*. 2001;4:75–79. Part 1.
8. Karanth KU, Nichols JD, Kumar NS, et al. Tigers and their prey: Predicting carnivore densities from prey abundance. *Procl Natl Acad Sci*. 2004;101:4854–4858.
9. Sanderson EW, Redford KH, Chetkiewicz C-LB, et al. Planning to save a species: the jaguar as a model. *Conserv Biol*. 2002;16(1):58–72.
10. Schaffer ML, Stein BA. Kutner LS, Adams JS, eds. *Precious Heritage: The Status of Biodiversity in the United States*. Oxford: Oxford University Press; 2000:301–322.
11. Wikramanayake E, Dinerstein ED, Robinson J, et al. An ecology-based method of defining priorities for large mammal conservation: the tiger as case study. *Conserv. Biol*. 1998;12:865–878.
12. Sanderson EW, Forrest J, Loucks C, et al. *Setting Priorities for the Conservation and Recovery of Wild Tigers: 2005–2015. The Technical Assessment*. New York and Washington, DC: WCS, WWF, Smithsonian, and NFWF-STF; 2006.
13. Nowell K, Jackson P, eds. *Status Survey and Conservation Action Plan; Wild Cats*. Gland, Switzerland: World Conservation Union; 1996.

14. Olson DM, Dinerstein E, Wikramanayake EE, eds. Terrestrial ecoregions of the world: a new map of life on earth. *Biol Conserv.* 2001;51(11):933–938.
15. Loveland TR, Reed BC, Brown JF, et al. Development of a global land cover characteristics database and IGBP DISCover from 1-km AVHRR Data. *Internat J Remote Sens.* 2000;21:1303–1330.
16. Friedl MA, McIver DK, Hodges JCF, et al. Global land cover from MODIS: Algorithms and early results. *Remote Sens Environ.* 2002;83:287–302.
17. Redford KH. The empty forest. *BioScience.* 1992;42(6):412–422.
18. Sanderson EW, Jaiteh M, Levy MA, et al. The human footprint and the last of the wild. *BioScience.* 2002;10: 891–904.
19. Karanth KU, Stith BM, Seidensticker J, Christie S, Jackson P, eds. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes.* Cambridge: Cambridge University Press; 1999:100–113.
20. Achard F, Eva HD, Stibig H-J, et al. Determination of deforestation rates of the world's humid tropical forests. *Science.* 2002;297:999–1002.
21. Jackson P, Seidensticker J, Christie S, Jackson P, eds. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes.* Cambridge: Cambridge University Press; 1999:50–54.
22. Sunquist ME, Karanth KU, Sunquist F, Seidensticker J, Christie S, Jackson P, eds. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes.* Cambridge: Cambridge University Press; 1999:5–18.
23. Miquelle DG, Smirnov EN, Merrill TW, Seidensticker J, Christie S, Jackson P, eds, et al. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes.* Cambridge: Cambridge University Press; 1999:71–99.
24. Miquelle DG, Stephens PA, Smirnov EN, Ray J, Redford KH, Steneck RS, Berger J, et al, eds. *Large Carnivores and the Conservation of Biodiversity.* Washington, DC: Island Press; 2005:179–207.