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From intent to action: A case study for the expansion of tiger conservation from southern India

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HIGHLIGHTS

- To conserve the tiger it is critical to enable the persistence of the species across larger landscapes.
- Establishing protected areas for tiger recovery remains one of the means of landscape approach.
- While the gazetting of protected areas is necessary to enable this, it is not sufficient.
- It is essential to benchmark and monitor the process that enable the recovery of tigers.

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ABSTRACT

To conserve a large, wide-ranging carnivore like the tiger, it is critical not only to maintain populations at key habitat sites, but also to enable the persistence of the species across much larger landscapes. To do this, it is important to establish well-linked habitat networks where sites for survival and reproduction of tigers are complemented by opportunities for dispersal and colonization. On the ground, expanding protection to areas with a potential for tiger recovery still remains the means of operationalizing the landscape approach. Yet, while the gazetting of protected areas is necessary to enable this, it is not sufficient. It is essential to benchmark and monitor the process by which establishment of protected areas must necessarily be followed by management changes that enable a recovery of tigers, their prey and their habitats. In this paper, we report a case study from the Cauvery and Malai Mahadeshwara Hills Wildlife Sanctuaries of southern India, where we document the infrastructural and institutional changes that ensued after an unprecedented expansion of protected areas in this landscape. Further, we establish ecological benchmarks of the abundance and distribution of tigers, the relative abundance of their prey, and the status of their habitats, against which the recovery of tigers in this area of vast conservation potential may be assessed over time.

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1. Introduction

Historically, wild tigers (*Panthera tigris*) have been threatened by the loss and fragmentation of their habitats, direct persecution for their body parts, as well as by prey depletion (Dinerstein et al., 2007; Nowell and Ling, 2007; Linkie and Ridout, 2011; Joshi et al., 2016). Tigers currently occur in a mere seven per cent of their former range, and number less than 3500 individuals (Dinerstein et al., 2007; GTI, 2011), thereby eliciting a commitment from the 13 range countries to double their tiger numbers by the year 2022 (GTI, 2011).

Among the key global tiger conservation strategies are landscape-based approaches to sustain existing populations and to attain recovery goals (Sanderson et al., 2006, 2010; Wikramanayake et al., 2010). Landscape-based approaches emphasize habitat connectivity as a means of enhancing gene flow, providing opportunity for dispersal, thereby increasing the persistence of populations, reducing the risk of inbreeding depression and local extinction, and finally, avoiding costly interventions such as translocation. The landscape-based approach has two key ingredients: first, it involves identification of key source populations (Sanderson et al., 2010; Walston et al., 2010), and secondly, it involves the consolidation and improvement of potential tiger habitat in and around these sites, as well as an enhancement of habitat connectivity within the larger landscape (Gubbi et al., 2016).

To achieve this, tiger range countries have established protected areas (PAs) that constitute key nodes with viable tiger numbers (Wibisono et al., 2011; Jhala et al., 2015; Gubbi et al., 2016). India has designated Tiger Reserves, where special federal funding is provided to enhance protection and management capabilities, and to address livelihood issues of local communities dependent on tiger habitats, to enable maintenance or improvement of tiger and prey numbers (NTCA, 2015).

However, the mere gazetting of PAs does not automatically lead to improved tiger conservation outcomes. Conservation success of PAs is dependent on improving institutional capabilities that underlie reserve management and on-the-ground protection (Bruner et al., 2001; Hilborn et al., 2006; Nolte, 2016). Further, these improved institutional capabilities must also demonstrably translate into improvement of habitat status and of focal animal abundances to values as close as possible to an area's ecological potential. There are relatively few examples, especially from the developing tropics, of careful assessments showing improvement in institutional capabilities after creation of a PA, and of subsequent ecological recovery against pre-gazettement baselines (e.g., Wegge et al., 2009). Such assessments can be useful not only in improving management strategies adaptively to deliver PA objectives (Hockings, 2003), but also in monitoring global tiger recovery targets set by various governments and multilateral conservation institutions (GTI, 2011). Further, while such institutional and ecological assessments are necessary, they may not be sufficient. Social and economic evaluations too may be necessary, given the fact that PAs are embedded within complex social and political landscapes that affect conservation outcomes.

In this paper, we report from the southern Indian state of Karnataka – one of the foremost regions globally for the long-term conservation of tigers – on institutional changes following the establishment and expansion of protected areas for tigers. We also set down a variety of ecological benchmarks, including tiger numbers, the distribution and relative abundance of prey, and the status of habitat, based on which the effectiveness and sustainability of the newly-established PAs may be assessed over time.

2. Study area

The Malai Mahadeshwara Hills Wildlife Sanctuary (906 km^2, MM Hills WS) and Cauvery Wildlife Sanctuary (1027 km^2, Cauvery WS) are part of an extensive (c. 6500 km^2) forested tract that emerge as an eastward spur of the Western Ghats hill range (Fig. 1). Besides being a unique tract of dry woodland savanna and riparian habitats, this region has held vast potential for the conservation of large and wide-ranging endangered species such as the tiger and the Asian elephant. Yet, attention to this region has been rather scant in global and regional conservation planning and prioritization efforts (Sanderson et al., 2006; Wikramanayake et al., 2010). As recently as 2011, just 26% ($\sim$1729 km^2) of this landscape, despite being dominated by forest lands under state control, was legally protected for wildlife. In one of the biggest PA expansions seen in recent decades in India, 1579 km^2 in this landscape falling within the state of Karnataka was gazetted as a PA (Gubbi et al., 2016). The elevation in legal protection of these forest tracts was the outcome of a constructive collaboration that engaged elected representatives, government officials, as well as members of civil society conservation groups (Gubbi et al., 2016). A key point of convergence across these groups was the need to maintain the value of this landscape as watershed of the River Cauvery, which sustains the farming and drinking water needs of 80 million people of southern India. Another salient aspect of these PA notifications was their acknowledgement that existing rights of traditional indigenous communities would continue as designated under The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (TSTOTFD, 2006).

Together with a similar PA expansion initiative in the neighbouring state of Tamil Nadu, over a four-year period between 2011 and 2014, the fraction of land under PA in this c. 6500 km^2 landscape rose nearly three-fold from 26% to 72%. This significant expansion of PA coverage has provided an unprecedented opportunity to help recover and sustain viable populations of large, endangered wildlife like tigers and elephants in this landscape.

The terrain in these PAs is undulating (232–1498 m above MSL) with scanty rainfall (average 700 mm/year). The vegetation is similar in both the PAs, dominated by tropical dry thorn and dry deciduous forests, interspersed with patches of woodland savannah, but also including tracts of moist deciduous and riverine forests along the Rivers Cauvery and Paalar, besides other larger streams. Geographic and demographic details about the study area are given in Table 1. The

Table 1
Key physical and demographic details of the Malai Mahadeshwara and the Cauvery Wildlife Sanctuaries, southern India.

Geographic and demographic details	Malai Mahadeshwara Wildlife Sanctuary	Cauvery Wildlife Sanctuary
Area (km^2)	906	1027
Location (WGS 84, Fig. 1)	11.76–12.16 77.25–77.67	11.95–12.41 77.16–77.78
Number of villages and hamlets within the protected area	19	31
Approximate human population[a]	50,722	10,155
Approximate livestock population inside the protected area	34,317	11,954
Length of interstate boundary	73 km	95 km
Number of vertebrates of conservation interest in the study area[b]	Endangered—5 Near Threatened—3 Vulnerable—10	Endangered—5 Near Threatened—3 Vulnerable—10

[a] 2011 Census figures of Government of India.
[b] Red list of the International Union for Conservation of Nature and Natural Resources (IUCN).

PAs host tiger (*Panthera tigris* ssp. *tigris*), leopard (*Panthera pardus fusca*), dhole (*Cuon alpinus*), sloth bear (*Melursus ursinus*), Indian fox (*Vulpes bengalensis*), possibly striped hyena (*Hyaena hyaena*), elephants (*Elephas maximus*) and several other large mammal species (Gubbi et al., 2014). The grizzled giant squirrel (*Ratufa macroura*), endemic to southern India and Sri Lanka, and the Madras tree shrew (*Anathana ellioti*), endemic to peninsular India, are also found in this landscape. The first-ever photographic evidence of the ratel (*Mellivora capensis*) from Karnataka state also comes from Cauvery WS (Gubbi et al., 2014). Other endangered species found here include the hump-backed mahseer (*Tor* sp.), and the Nilgiri barb (*Hypselobarbus dublus*) fish species (Gubbi et al., 2015), besides the white meranti (*Shorea roxburghii*), an endangered tree.

Prior to their declaration as a PA, the Reserved Forests (RFs) of the MM Hills WS and parts of Cauvery WS were managed under a 10-year management plan, where the focus was on silvicultural operations such tree planting, commercial harvest of non-timber forest produce and similar extractive activities. There was little emphasis on protection against fire, on curtailing poaching and regulating other pressures. The government funds available to establish anti-poaching camps, acquire patrol vehicles, and other protection infrastructure, or to build/strengthen physical barriers to prevent movement of conflict-prone species into croplands and human settlements were limited. Hence, the infrastructure available to manage the areas for wildlife conservation was minimal.

3. Methods

3.1. Institutional monitoring

Following the notification/expansion of PAs, we tracked significant structural and administrative changes that ensued to enable a more effective management focus on wildlife conservation. For example, once areas previously notified as RFs were converted to PAs, existing Forest Ranges (basic forest administrative units) were reorganized to reduce the size of each forest range, which, coupled with greater staffing, made for intensified protection and management. We also tracked additional infrastructure provided by the government to improve management and protection effectiveness. We also obtained information regarding poaching incidences detected, and on infrastructure (patrol roads, anti-poaching camps, wireless equipment, physical barriers to reduce human-wildlife conflict and other details) created from the Annual Plan of Operation (APO) of each PA. However, some of these data, such as patrolling intensity and patterns, reflect available estimates, rather than systematic measures.

3.2. Biological monitoring

We also strived to assemble baseline data that would reflect the status of key biological parameters in this landscape. Among these, we analysed a time-series of satellite imagery to assess trends in forest cover in the period preceding the gazettement of these areas as PAs. We also followed this up with baseline estimates of the abundance of tigers, and of the relative distribution and abundance of their prey.

3.3. Changes in forest cover

We assessed directional change in forest cover in this landscape over the last 15 years by choosing a conservative method that isolated and extracted the signature of directional change from seasonal and inter-annual variations in forest cover. We used the 16-day MODIS vegetation indices product, in which NDVI is computed from atmospherically corrected bi-directional surface reflectances that have been masked for water, clouds, heavy aerosols, and cloud shadows. We gathered images from 2000 to 2014, only selecting images corresponding to the dry season from December through February (also with the fewest cloud artefacts). For images from each year, we selected pixels from the image stack that corresponded to the maximum NDVI. We then used this composite image of the 'greenest' pixel for each year in inter-annual trend analyses. To assess monotonic inter-annual trend, we used the Theil–Sen estimator – the median of all pairwise slopes for a given year

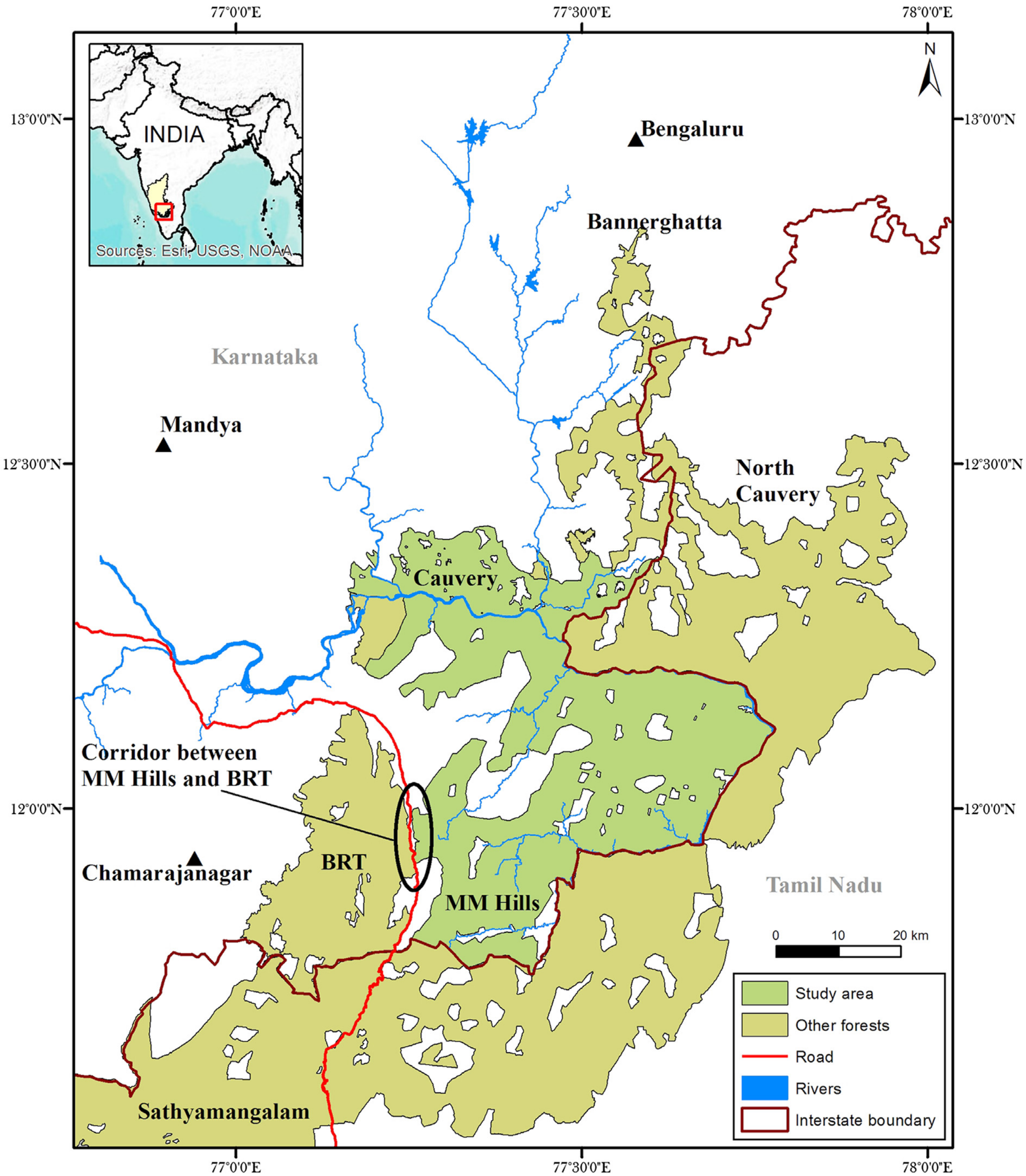

Fig. 1. Protected areas and reserved forests landscape that contains Malai Mahadeshwara and Cauvery Wildlife Sanctuaries, southern India.

and all its subsequent years in a time series (Siegel, 1982) – obtaining a final image of the percent annual change in NDVI. Separately, we also obtained the median NDVI for each range of MM Hills WS and Cauvery WS, for each year between 2000 and 2014. This was plotted not only to provide NDVI estimates, but also to assess local-scale variations in trend.

3.4. Baseline estimates of tiger abundance and prey relative abundance

Following, a systematic reconnaissance survey of motorable roads (∼768 km) and forest trails (∼312 km), suitable camera trap locations were selected based on evidence indicating current use of the area by large carnivores and where probability of photographing large carnivores was high. Thereafter, we optimized trap spacing and locations, striving to maximize spatial sampling, given local logistical constraints. The entire study area was divided into ten sampling blocks for easier logistics and camera trapping was carried out in each of the sampling blocks in a single sweep following standard protocols (Karanth et al., 2011) using Panthera V4 passive infrared motion detection digital camera traps. Camera trap units were deployed at 809 camera trap locations resulting in a total camera trapping effort of 11,268 trap days (Table 3). Spatial coverage and intensity of camera trapping effort is shown in Figure A1 in Supplementary material. Full details of the protocol are provided in the Supplementary Material (see Appendix A).

Using the camera trap photo-captures, we also calculated a relative abundance index (RAI) – the number of independent photographs of a species per 100 camera trap-days (O'Brien et al., 2003) – for both wild and domestic prey. Photo captures of the same species that were more than five minutes apart at the same camera trap location were considered as independent events. Although our preliminary work did not include efforts to estimate the density and biomass of prey species, earlier work does show that there is a linear relationship between RAI and absolute abundance estimated through other rigorous methodologies (Carbone et al., 2001; Rovero and Marshall, 2009).

4. Results

4.1. Institutional/structural changes after PA creation

Three RFs that were contiguous and were sandwiched between BRT and Cauvery WS were designated as the new MM Hills WS. The nine RFs that were adjoining the existing Cauvery WS were also given the status of a PA and amalgamated into the existing PA (See Table A1 in Supplementary material). The establishment/expansion of PAs brought in important structural changes in both the PAs (Table 2). Key among them are the downsizing of administrative units, the enhancement of staff strength, and the creation of more physical infrastructure (e.g., anti-poaching camps & patrolling roads) as shown in Table 2.

4.2. Functional/management changes after PA creation

Beyond hard infrastructure, the change resulted in the creation of key management processes such as an improved patrolling effort. Although not measured rigorously, it is clear that an increased capacity and utilization of protection infrastructure is associated with an increase in the detection and prosecution of poaching cases (Table 2). Similarly, with the creation of the PAs, the attitude and perspective of frontline staff seem to be better aligned towards the protection of species and habitats, a change that is qualitative and not easily measured, but nonetheless one that makes an important difference to conservation outcomes on the ground.

4.3. Biological baselines and trends

4.3.1. Forest cover

Barring small regions around Gopinatham in Cauvery WS, the overall trend in forest cover over most of this landscape during the assessment period was one of decline (Fig. 2). Many areas, especially in the forest ranges of Hanur (Cauvery WS), Hanur (MM Hills WS), the southern portions of Cowdalli (Cauvery WS) and the northern portions of Ramapura (MM Hills WS) showed a monotonic annual decline of NDVI of 1.5% or more. At the same time, most of the forest ranges of MM Hills WS, especially Paalar (MM Hills WS), Hoogyam (MM Hills WS), and MM Hills (MM Hills WS and Cauvery WS) appeared to hold their forest cover over this 15-year period. As a result, forest ranges have diverged significantly in terms of their median NDVI over time (Fig. 3).

4.3.2. Tigers and prey

We obtained a total of 273 tiger photo-captures (236 of adult tigers and 37 of cubs), from which we were able to identify 11 unique individual adult tigers, 3 unique cubs, and one individual animal had only one flank captured in the camera trap. In MM Hills WS we documented one female with three cubs, confirming that tigers were indeed breeding in the study area. The density and abundance values were similar with both SECR and SPACECAP software packages.

The relative abundance and spatial distribution of key tiger prey, both wild and domestic, as well as of tigers themselves, is shown in Fig. 4.

Analyses under the SECR package yielded a density of 0.66 tigers/100 km^2 and an abundance estimate of 11.26 (SE 0.216) for the MM Hills. The results were similar in the SPACECAP package with 0.63 tigers/100 km^2 and the abundance estimate was 10–12 tigers (SD 0.861) (see Table A2 in Supplementary material).

5. Discussion

5.1. Institutional and management changes

The creation of MM Hills WS, and the substantial expansion of the Cauvery WS, have been accompanied by institutional, infrastructural and management changes to enable species conservation in this landscape. For instance, the increased

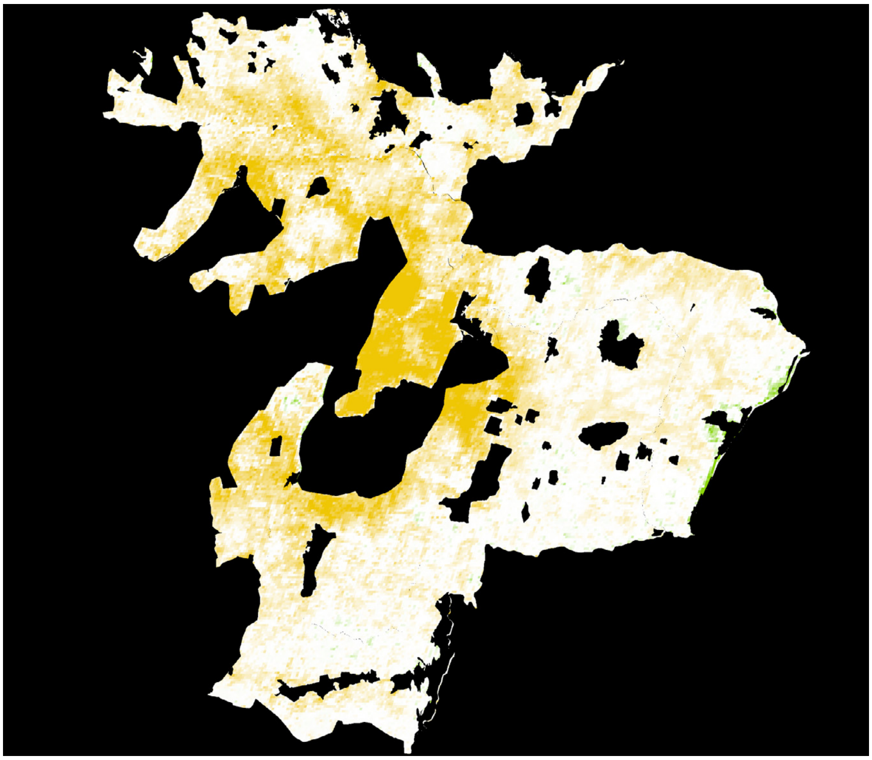

Fig. 2. Overall trend in forest cover over the MM Hills and Cauvery Wildlife Sanctuaries landscape during the period 2000–2014 indicating regions with a significant 'browning' trend, and areas without significant changes.

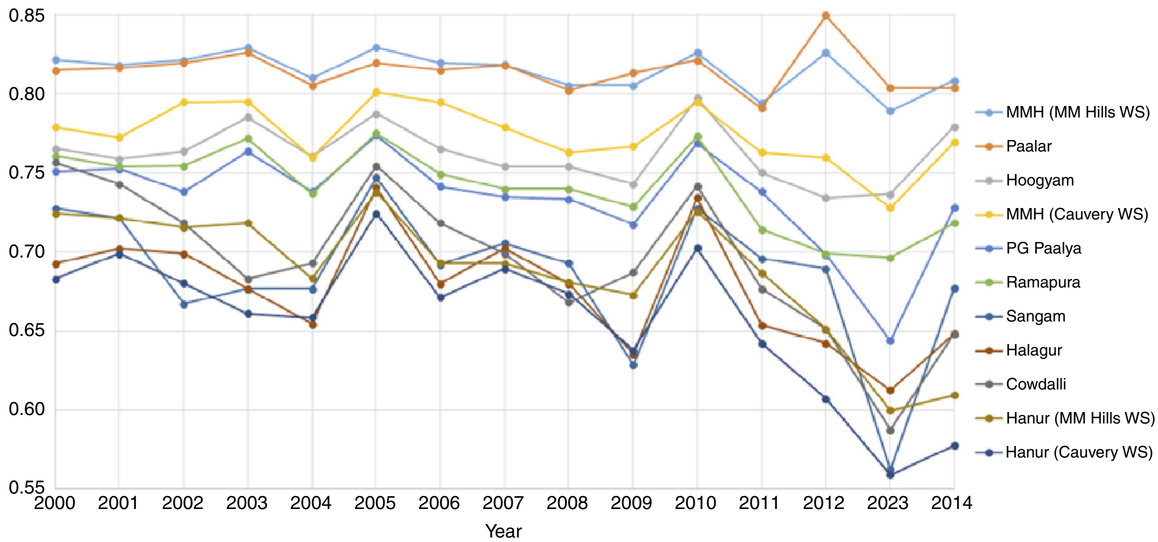

Fig. 3. Inter-annual trends (2000–2014) in range-wise Normalised Difference Vegetation Index (NDVI) in MM Hills and Cauvery Wildlife Sanctuaries.

number of anti-poaching camps has led to the culture of patrolling against activities that are detrimental to wildlife. If such increased efforts are documented more rigorously by the Forest Department, they could provide critical correlate of wildlife and habitat recovery. In addition, creating baselines of the human footprint, and of wildlife distribution in relation to anthropogenic factors, especially wildlife poaching, large-scale livestock grazing and habitat degradation, within these PAs could strengthen park management decisions. This may also help improve enforcement and assess the effectiveness of existing protection and recovery efforts. Likewise, a logical progression of the landscape-approach to wildlife conservation would be the identification of other RFs that could be included under PAs, without undermining the interests of local communities (see Table A3 in Supplementary material).

Table 2
Comparative administrative changes and protection infrastructure at the study sites before and after gazetting/expansion of Malai Mahadeshwara and Cauvery Wildlife Sanctuaries in southern India.

Protected area infrastructure	Malai Mahadeshwara Hills Wildlife Sanctuary		Cauvery Wildlife Sanctuary	
	Before (May 2013)	After (January 2015)	Before (December 2011)	After (January 2015)
Number of administrative ranges	4	7	4	5
Number of anti-poaching camps	11	27	12	30
Protection staff strength	157	221	78	195
Number of patrolling vehicles	6	13	6	9
Network of patrolling roads (km)	166	206	260	468
Wireless sets				
Stationary sets	15	15	6	8
Mobile sets	7	7	16	18
Walkie-talkie	70	70	53	73
Number of law enforcement check posts	2	2	0	3
Wildlife poaching cases detected per month[a]	0.88 (SD 1.1)	1.25 (SD 0.85)	0.58 (SD 0.75)	1.14 (SD 1.24)
(Mar 2008–Jan 2015)	(54 cases in 61 months)	(25 cases in 20 months)	(26 cases in 45 months)	(49 cases in 43 months)
Length of physical barriers (km)				
Solar electric fence	8	41	6	82.5
Elephant proof trench	53.7	114.5	15	86

[a] Number of poaching cases detected/per month.

Table 3
Results from camera trapping exercise conducted during November 2014–January 2015 and January–March 2014 in Malai Mahadeshwara and Cauvery Wildlife Sanctuaries, southern India.

	MM Hills	Cauvery
Length of motorable roads used for sampling	258 km	520 km
Length of trails used for sampling	301 km	2.7 km
Area of camera trapping (excluding human habitations)	807 km^2	961 km^2
No. of camera trap locations/stations	463	332
No. of sampling occasions (trap days of 24 h)	16	11
Total camera trapping effort (trap-days)	7620	3648
No. of tiger photographs	249	24
No. of tiger photos/100 trap nights	2.5	0.2
No. of individual adult tigers identified	10[a]	2
Tiger density (no of adult individuals/100 $km^2 \pm$ SE)	0.66 (0.21)	Not applicable

[a] One individual tiger is common to both Malai Mahadeshwara Hills and Cauvery Wildlife Sanctuaries.

5.2. Biological baselines

The results of this study establishes baseline estimates for tiger distribution and abundance for these two protected areas, which were hitherto unavailable (Goodrich et al., 2015), and creates a baseline against which it becomes possible to monitor temporal changes in large carnivore numbers in these newly established/expanded protected areas. With an improvement in protection and management of these PAs, we expect the density of large carnivores, especially tigers, and ungulate prey to improve over the coming years. The results from prey monitoring provide an overall indication about the relative abundance and distribution of prey species.

Forest ranges with a relatively greater interface with densely-settled production landscapes (especially around Hanur and Cowdalli) seemed to show greatest loss in forest cover. Ranges that were included in the Cauvery expansion and in the northern portions of MM Hills, that were hitherto managed for silvicultural operations and extractive activities, were experiencing significant year-on-year decline in forest cover and now need better protection.

This analysis now provides the baseline against which to assess if elevating protection status, together with improved management capabilities and efforts in the newly expanded / created PAs helps in habitat recovery. Given most of the pressures on habitat come from the dependence of local villages on forest biomass (mainly for fuelwood and fodder), engaging and working with these communities would be very important for forest recovery, in tandem with law-enforcement efforts.

The regions of widespread distribution and high abundance of livestock (Fig. 4), taken together with the areas of declining NDVI values, suggest that livestock may be a factor in forest cover decline. In addition, the relationship between the distribution and abundance of livestock, in relation to other ungulates, especially grazers such as gaur and chital, suggests that there may be scope for their recovery in parts of the landscape where their distribution is currently sparse, and livestock presence is intense. Nevertheless, before implementing any action to lower livestock numbers, it would be very important to understand the significance of livestock in the local rural economy, and to ensure that measures to reduce their numbers

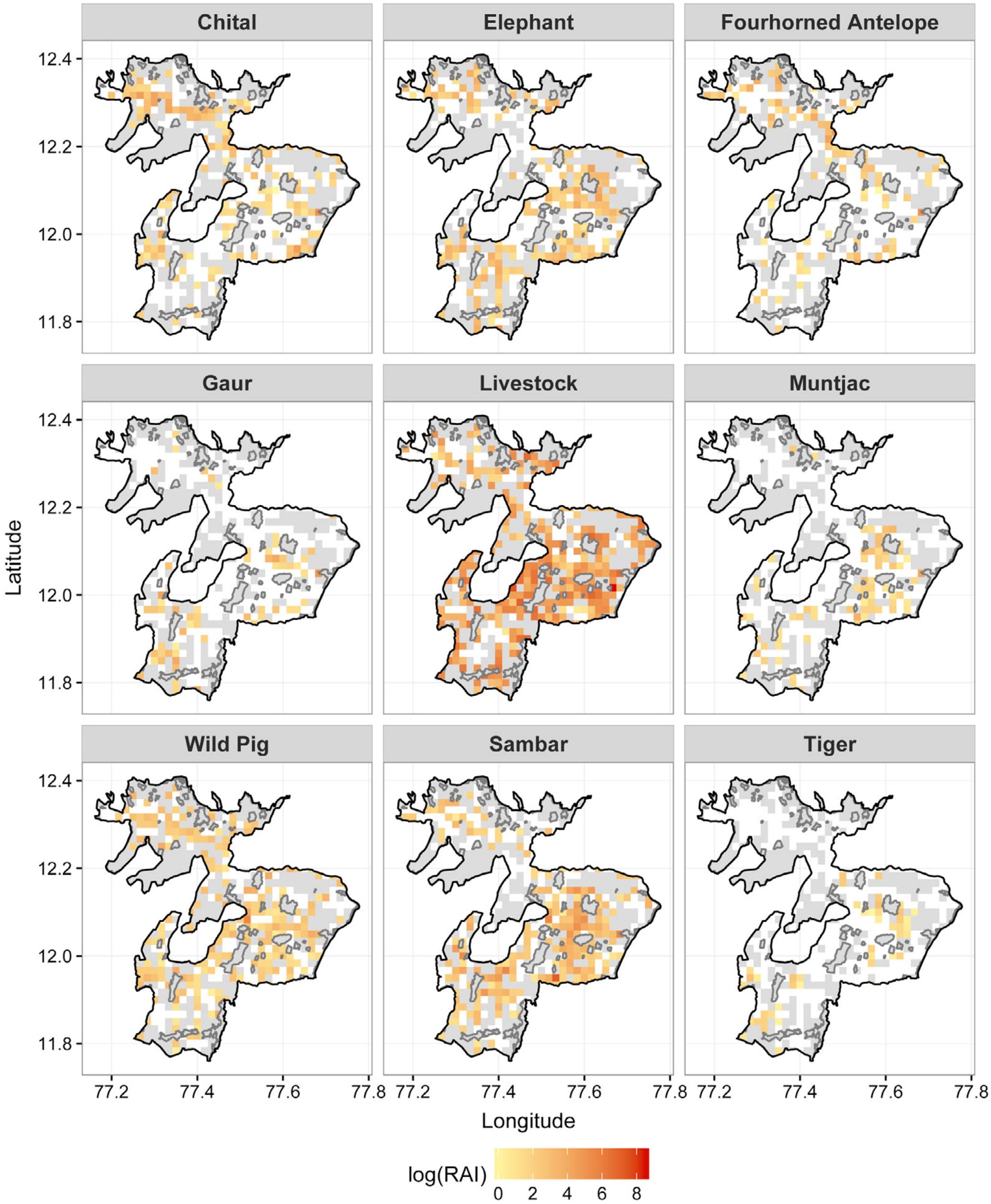

Fig. 4. Relative abundance and distribution of prey species.

are taken with the participation and support of the local community. If this is done right, we believe that there is significant scope for prey recovery in this landscape, which would be a critical enabler of tiger recovery.

5.3. Value of this landscape

This landscape with all the PAs and RFs were undervalued and had received little attention in the past though they have high potential to hold one of the largest contiguous populations of tigers and their prey. The current density estimates of tigers within the study area is higher than some tiger reserves in the country (NTCA, 2014) clearly highlighting the importance of both these protected areas for tiger conservation. With adequate funding and protection to habitat, we anticipate a decline in threats and a recovery of prey, which should enable tigers in this landscape to achieve higher densities. Alongside, simple and reliable biological monitoring should become a part of regular management practice.

Although poaching of prey species continues to be a cause of concern there has been a marked improvement in detection of poaching incidences as demonstrated in our results. The increased detection of poaching is perhaps due to the increased patrol efforts by the frontline staff that was supported through increased infrastructure. Reduction of poaching threat should be one of the critical factors that management should prioritize in the landscape.

5.4. Implementing a landscape approach to tiger conservation

We hope that the establishment of PAs and the subsequent conservation efforts undertaken will lead to a successful tiger and other wildlife species conservation effort. But merely providing legal cover is not enough; actual changes in on ground and improved capacity to conserve wildlife are very much needed. Keeping a finger on the pulse through rigorous assessment to demonstrate improvements in conservation outcomes is also a significant need. In addition, creating sustained local support by undertaking direct community-based interventions is also critical in landscapes where tigers survive amidst a matrix of human habitations, but this needs to be implemented with sound monitoring mechanisms (Gubbi et al., 2009) to ensure that key conservation threats are reduced.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.gecco.2016.11.001.

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Supplementary material:

From intent to action: a case study for the expansion of tiger conservation from southern India

Figure A1: Spatial coverage and intensity of camera trapping effort

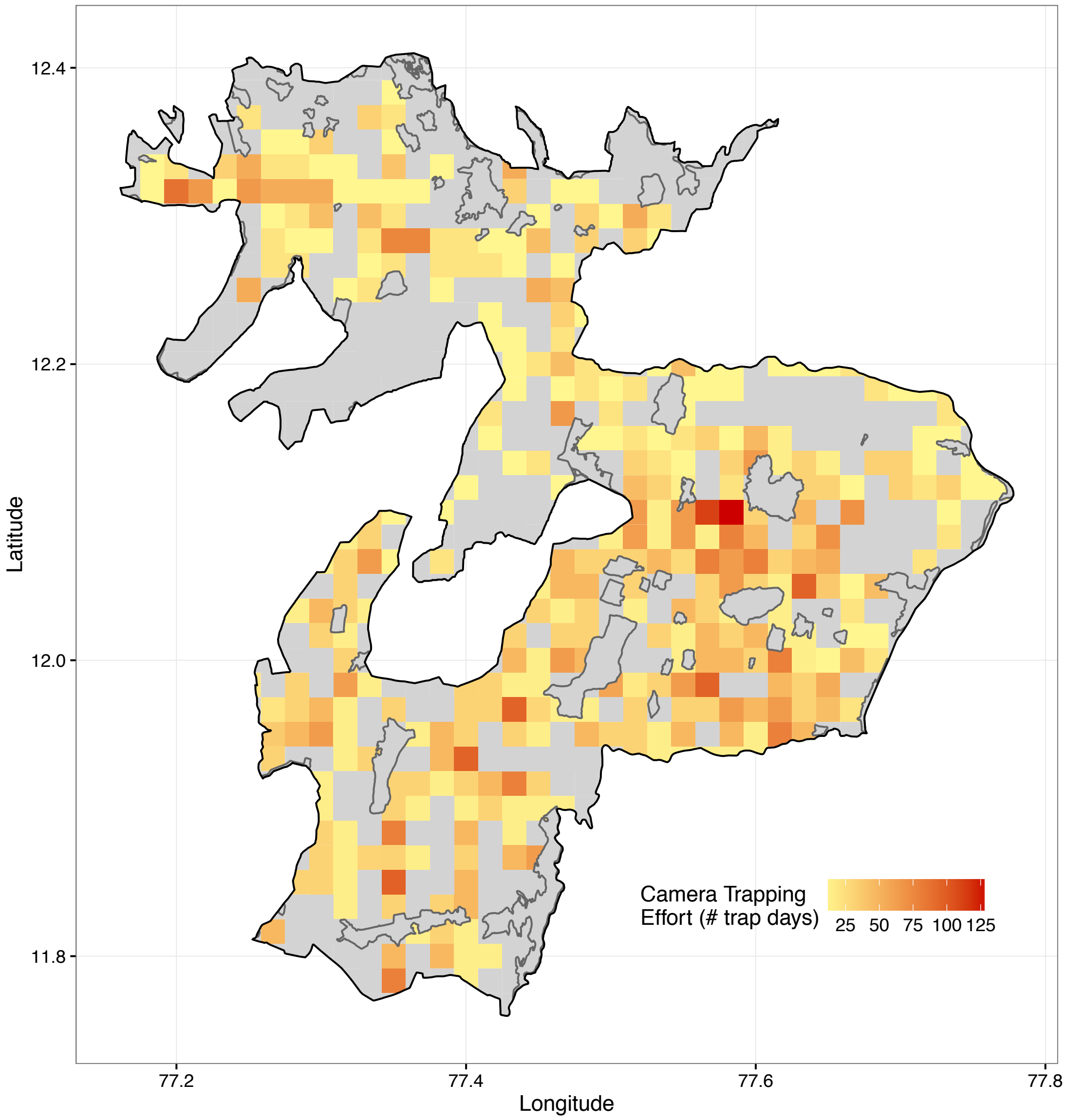

Table A1: Reserved forests included in the MM Hills and Cauvery Wildlife Sanctuaries, with area, (see text for further details).

Reserved forests added to Malai Mahadeshwara Wildlife Sanctuary	
Reserved Forests	Area (km^2)
Yediyarahalli	442.7
MM Hills	388.4
Hanur	74
Reserved forests added to Cauvery Wildlife Sanctuary	
Chilyalur	108.8
Chillindvad	100.9
Cowdalli	90
Mugur	68.5
Basavanabetta	62.7
Mambetta	27
Dhangur	26.3
Chavarkal	12.2
Chunchi East	4.5

Camera trapping protocol

The study was carried out between January and March 2014 in Cauvery WS (11 sampling occasions) and between November 2014 and January 2015 in MM Hills WS (16 sampling occasions). We assume that over a sampling occasion, the population being sampled was both demographically as well as geographically closed.

Individual tigers were identified using pictures of both flanks of the animals. Pictures were excluded from the analysis when identity was uncertain (e.g., image from single flank or unclear image). Cubs that appeared to be less than two years were also excluded from the analysis, as they are known to have different capture probability compared to the adults.

Capture details, trap deployment and habitat matrix were developed as per protocols suggested under SECR and SPACECAP packages (Royle et al., 2009; Gopalaswamy et al., 2012; Efford 2015). Habitat matrix was created by digitizing Google Earth imagery (Google Inc. Ver 7.1.5.1557). The input matrices were used to estimate tiger density using SECR and SPACECAP, two spatially explicit capture-recapture analysis packages that incorporate spatial information (capture locations) into modelling and estimating capture probabilities in a Bayesian framework (Royle et al., 2009; Gopalaswamy et al., 2012; Efford 2015). For the SECR analysis, we used a half-detection function with the parameter g_0 (magnitude of detection function) constant across animals, occasions and traps. The data was analysed in the SPACECAP package with a spatially explicit, non-behavioural response and half-normal detection function (Gopalaswamy et al., 2014). The analysis was carried out only for MM Hills WS, analyses could not be carried out for Cauvery WS as the sample size was very low.

The original goal of the camera trapping efforts was to estimate the leopard densities in the landscape through camera trapping. The results reported here are from camera trapping data incidentally obtained during an effort to estimate leopard abundance in the region. Given that the methodology is virtually the same for both leopards and tigers, this study on leopards provides valuable information on tigers as well.

Table A2: Summary of tiger density estimation in Malai Mahadeshwara Hills Wildlife Sanctuary using Spatially Explicit Capture-Recapture (SPACECAP) software for a buffer of 2 km.

	Posterior Mean	**Posterior SD**	**95% Lower HPD Level**	**95% Upper HPD Level**
σ	7300.73	565.60	6230.66	8428.04
λ_0	0.009	0.0018	0.0066	0.013
Ψ	0.133	0.037	0.0646	0.208
N_{super}	10.69	0.861	10	12
D	0.63	0.051	0.591	0.709

σ – Scale parameter of detection function, λ_0 - Expected encounter rate of an individual tiger whose home range is exactly at the trap location, Ψ – The ratio of the number of tigers actually present within the state space, N_{super} – Population size of individuals, D – Density of tigers/100 km^2

Table A3: Reserved forests both in Karnataka* and in the adjoining state of Tamil Nadu[&] that are contiguous to MM Hills WS, Cauvery WS, Satyamangalam Tiger Reserve and have the potential for tiger and prey recovery.

Name of the reserved forest	**Area (km^2)**
Muneshwarabetta	15.73*
Sathegala-Jageri	37.66*
Kestur Extension	16.74[&]
Kestur Addn.	1.83[&]
Naglur	5.43[&]
Ulibanda	32.84[&]
Ubbarani	41.55[&]
Mallahalli	40.18[&]
Natrapalaiyam	48.26[&]
Badanavadi & Extension	110.13[&]
Pachiapalamalai	12.72[&]
Ennamangalam	21.77[&]
Tamarakarai	34.98[&]
Bevanurmalai & Extensions	57.82[&]
Voddappatti	76.72[&]
Pennanagaram & Extension	50.44[&]
Guttirayan	66.46[&]
Morappur	76.67[&]
Pikkilimalai	22.20[&]
Taggatti	42.46[&]
Urigam	31.51[&]
Bilikal	52.25[&]
Kestur	53.89[&]
North Bargur	409.80[&]
North Bargur	22.67[&]

South Bargur	268.88&
North Bargur	40.38&
Biligundlu	60.69&
Kesaraguli and Extension	31.74&
Total	**1784.54**

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