TIGERS IN THE TRANSBOUNDARY MANAS CONSERVATION COMPLEX: CONSERVATION IMPLICATIONS ACROSS BORDERS

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ABSTRACT
Tiger *Panthera tigris*, is used as a flagship or umbrella species in conserving wildlife and wild areas in many parts of Asia. We used remotely triggered camera traps and capture-recapture framework within Manas National Park in India and Royal Manas National Park in Bhutan to estimate the abundance and density of tigers in the Transboundary Manas Conservation Complex (TMCC). A total of 102 camera traps pairs were used in three ranges to cover more than 400 km² area. We captured 87 photographs of 14 individually identified tigers (eight males and six females), during the 5,955 camera-trap night survey period. The population estimated was 15 (±SE 2.64) individuals with a 95 per cent confidence interval range of 15 to 29. Tiger density estimates using ½ MMDM (Mean Maximum Distance Moved) and using MLSECR (Maximum Likelihood Spatially Explicit Capture Recapture) analysis was 1.9 (±SE 0.36) and 0.75 (±SE 0.21) individuals/100 km² respectively. TMCC is an important landscape, crucial for the future of tigers, and effective management of biodiversity should extend beyond the borders of protected areas and across political boundaries.

KEYWORDS: *Panthera tigris,* Manas, India, Bhutan, camera traps, abundance, density

INTRODUCTION

Knowledge of what species is present, their relative abundance and distribution within an area is essential for effective conservation management (Sheng et al., 2010). Well-designed monitoring programmes can obtain such information and provide robust scientific data to wildlife managers on the long-term population or biodiversity trends (Pereira & Cooper, 2006; Marsh & Trenham, 2008). In the absence of species abundance information, conservation management decisions are often based on educated guesses, which may result in erroneous decisions that can be counterproductive for conservation (Blake & Hedges, 2004).

In the Indian subcontinent, conservation of the Royal Bengal Tiger (*Panthera tigris tigris)* is at a crucial stage. The extirpation of tigers from tiger reserves has led to the growing realization that this subspecies is declining rapidly where they were thought to be thriving (Wright, 2010). It was found that due to massive forest destruction in India, as well as poaching of tigers and the loss of their prey base, much of the tiger populations disappeared in the last decade. In Bhutan, the tiger can be found from sub-tropical jungles near the Indian plains to above tree line on the Tibetan border (Dorji & Santiapillai, 1989). The Royal Government of Bhutan (RGoB) is committed to conserving this species and has

Deploying camera traps in Manas National Park, India © WWF India

set aside more than 51 per cent of the country's total geographic area as protected areas in the form of National Parks and Biological Corridors. Global initiatives to conserve tigers by international organizations and NGOs have helped in raising awareness of the precarious state of this species. However, despite huge financial investment and effort from these agencies and nations, tiger numbers continue to dwindle in most of the tiger range countries.

Global and regional level initiatives will need to be anchored to on the ground actions at the local level. Conservation actions and initiatives at the local level are crucial to realize the global mission of preventing extinction of tigers in the wild. It is with this objective that we initiated a tiger monitoring study in the Royal Manas National Park (RMNP) in Bhutan and the Manas National Park (MNP) in India as the core area of the Transboundary Manas Conservation Complex (TMCC) (Borah et al., 2012). The complex is an important tiger conservation unit stretching across India and Bhutan. It is also supposed to be the only landscape in South East Asia sustaining the occurrence of tigers living close to the timberline and predating upon mountain ungulates (Wikramanayake et al., 1998). Tigers in this complex are known to traverse between the political boundaries since the whole complex is a contiguous stretch of habitat conducive for its survival.

STUDY AREA

TMCC straddles the Indo-Bhutanese border from the Ripu Reserve Forest in India in the west, to Bhutan's Khaling Wildlife Sanctuary in the east, to Jigme Singye Wangchuk National Park in Bhutan to the north. Thus, the TMCC encompasses the whole of India's Manas Tiger Reserve and the group of protected areas in southern Bhutan. The area is home to one of the richest diversity of wildlife and vegetation in the region.

The TMCC is located at the junction of Indo-Gangetic and Indo-Malayan realms and is a key conservation area in the *Jigme Dorji-Manas-Bumdaling* conservation landscape in the eastern Himalayan eco-region (Wikramanayake et al., 2001). It is also an identified Tiger Conservation Landscape (#37 *Northern Forest Complex – Namdapha - Royal Manas*, Sanderson et al., 2006). Habitats range from tropical grasslands at 40 to 150 m through subtropical forest at 300 m to warm broad-leaved forest above 1000 m reaching up to 2000 m. The Manas River flows through RMNP and MNP with both parks functioning as important watershed areas.

The complex is home to endemic and globally threatened species like Golden langur (*Trachypithecus geei*), Pygmy hog (*Porcula salvania*) and the endangered Bengal florican (*Houbaropsis bengalensis*) as well as of Royal

Bengal tiger, Clouded leopard (*Neofelis nebulosa*), Leopard (*P. pardus*), Asian elephant (*Elephas maximus*), Asiatic water buffalo (*Bubalis bubalis*), Gaur (*Bos gaurus*), Greater one-horned rhinoceros (*Rhinoceros unicornis*) and White bellied heron (*Ardea insignis*). The landscape is noted for its spectacular scenery with a variety of habitat types that support a diverse fauna with nearly 30 threatened mammals and about 35 threatened birds.

MATERIALS AND METHODS

We used remotely triggered camera-traps and a capture-recapture framework to estimate the population size of tigers. Photographic capture-recapture sampling is a reliable technique for estimating the abundances of tigers and other secretive animal species that can be identified individually from their natural markings (Karanth & Nichols, 1998; O'Brien et al., 2003; Karanth et al., 2004; Chauhan et al., 2005; Jhala et al., 2008, 2011; Sharma et al., 2009). The camera-trapping programme was designed primarily to determine the abundance and density of tigers in TMCC, but also provided extensive data on the occurrence of co-predator's and prey species. Using these data our intention was to establish baseline information that would facilitate the conservation of tigers and several other species in TMCC as a single conservation unit.

The camera-trapping study across the trans-boundary area was conducted within Bansbari and Bhuyanpara Ranges of MNP in India and the Manas Range of RMNP, comprising a minimum convex polygon (MCP) area of 436 km^2. Camera-traps were put in 102 locations across the three ranges within TMCC from November 2010 to February 2011. A pair of camera traps was put in each 4 to 6 km^2 grid cell size, with the distance between each camera varying from a minimum of 1.75 km to maximum of 3.15 km. The camera-traps were deployed in the best possible locations within each grid to ensure coverage of the entire sampling area, avoiding gaps large enough so as to satisfy the assumption that no animal had a zero probability of being photographed. The survey was, therefore, designed to cover the study area homogeneously to maximize the chance of photographing all animals present in the area (Karanth & Nichols, 1998). We kept all the cameras operational for 24 hours a day for 64 days, except in cases of malfunction or damage caused by elephants. Each day (24 h) was therefore defined as a sampling occasion (Otis et al., 1978). Our duration of camera-trapping for 64 days was adequate for assuming demographic closure (Otis et al., 1978) of the study population, as previous studies on large cats has suggested trapping periods of 2-3 months

Camera trap © WWF India

as sufficiently short to assume that no population change occurs during the study (Karanth, 1995; Karanth & Nichols, 1998; Silver et al., 2004). In MNP, all camera units were mounted on trees, on poles or in steel cages made specifically for the cameras. The cameras were placed 3-4 m apart on either side of a path or trail, with the sensor set at 20-40 cm from the ground. In RMNP, the cameras were placed 6-7 m away from each other at a height of 45 cm from the ground and positioned in such a way that two cameras were not in the same line of view to avoid the flash of one disturbing pictures on the other camera. Efforts were made to place two cameras at each location, but sometime in RMNP, certain camera stations could accommodate only one camera. In such cases, we placed the other camera few metres away from the location (10-15 m), forward or backwards, along the same trail.

In addition to monitoring tigers, this exercise was also meant to record biodiversity, particularly the fauna of TMCC, so we set the sensitivity of camera to 'high' for maximizing capture of wildlife in the area. To deter and avoid damage from elephants in RMNP, we placed fresh elephant dung on our cameras and camouflaged them to blend with surrounding environment. The cameras were checked on a daily basis by a team of researchers at MNP and monitored twice a month where ever possible in RMNP (some of the cameras traps could only be monitored once a month due to logistical constraints). Although the same camera locations were maintained throughout the study duration, we shifted the cameras 100-200 m from the original location whenever a sign of

Researchers recording data © WWF India

trap shyness was observed. We identified the photo captured individual tigers by its stripe pattern. Every photo-captured tiger was given a unique identification number (e.g. TM1M, TM2F etc) after carefully examining the position and shape of stripes on the flanks, limbs, forequarters and sometimes even tail (Schaller, 1967; Karanth, 1995; Franklin et al., 1999).

DATA ANALYSIS

- **Abundance estimation**

We developed individual capture histories for tigers in a standard 'X-matrix format' (Otis et al., 1978; Nichols, 1992). These were analyzed using models developed for closed populations in the programme CAPTURE (Rexstad & Burnham, 1991). An issue with the use of standard closed population models to estimate abundance is the assumption of demographic and geographic closure within the study period. In the majority of population studies on large, long-lived mammals, such as tigers, the sampling period is generally adequately short that the assumption of demographic closure (i.e. no births or deaths within the sample population) is logical. However, violation of the assumption of geographic closure (i.e. no animals move in or out of the study area during sampling) is much more likely. We assumed that the sampled population was demographically closed, as tigers are long-lived animals (Otis et al., 1978; Karanth, 1995) and our sampling period was relatively short. We formally tested population closure using open Pradel models implemented in the programme MARK. In Pradel models, we compared Akaike Information Criteria corrected for small sample size (AICc) scores between a model in which recruitment and survival were constrained to zero and to one, respectively (representing population closure), and an open model in which these parameters were estimated based on observed data. The parameters, recruitment and survival, correspond to immigration and fidelity, assuming a population is demographically closed (Boulanger & McLellan, 2001; Harihar et al., 2009; Borah et al., *in press*). Jackknife estimator (Otis et al., 1978) has been used successfully in earlier photographic capture studies (Karanth, 1995; Karanth & Nichols, 1998; Karanth et al., 2004; Maffei et al., 2004; Simcharoen et al., 2007; Wang & Macdonald, 2009) to estimate capture probabilities and population size. However, it has been seen that the Jack-knife heterogeneity model appears less robust than other models when data are sparse or capture probabilities low and strongly heterogeneous (Boulanger et al., 2002, Harmsen et al., 2010, Gray & Prum, 2011). Based on the capture recapture history generated from our study, we generated parameter estimates under the M_b model which turned out to be the best-fit model for the present study in the programme CAPTURE.

- **Density estimation**

We estimated tiger densities (per 100 km^2) by dividing the population size (N) by the effective sampled area, based on our abundance estimates. The effective sample area was computed following the approach developed by Wilson & Anderson (1985), using the half of the mean maximum distance moved (HMMDM) method, in which a buffer of HMMDM for all individuals captured at more than one camera-trap location is added to the trapping grid polygon (Karanth & Nichols, 1998). We also obtained density estimates using full maximum likelihood spatially explicit capture recapture (MLSECR) in the programme DENSITY (DENSITY 4.4, www.otago.ac.nz/density), which did not rely upon closed population estimates from CAPTURE. The buffer width around the trapping grid was set at 10 km and we assumed a half-normal spatial capture probability function and a Poisson distribution of home-range centres for estimating density.

RESULTS

We photo captured 14 individually identified tigers comprising of eight males and six females, during the 5,955 camera-trap night survey period (see Annex). Four out of the 14 tiger identified were found to be using both the areas in MNP and RMNP. Capture frequencies varied from one to five for the individuals. In MARK, the open Pradel model estimated survivorship (θ) at 0.98 (±SE 0.008) and recruitment (f) at 0.02 (±SE 0.008) for the tiger population. The constrained Pradel model, in which θ was set at 1.0 and f at 0.0 (the closed model), was better supported (ΔAICc 771.93) than the open model (ΔAICc 856.5). Therefore, we found it reasonable to consider the population closure for tigers to justify analysis within a closed capture recapture framework.

- **Abundance**

The overall model selection test ranked M_b (behavioural response to capture) as the best model (Criteria rated 1) in CAPTURE. Tests for the affect of a behavioural response ($X^2 = 15.77$, df=1, P=0.00007) supported the suitability of the model in CAPTURE. The probability of detecting an individual on at least one sampling occasion (Average p-hat) was 0.03, while the estimated probability of recapture (average c-hat) was 0.12. The population estimate using M_b with the zippin estimator was 15 (±SE 2.64) individuals with a 95 per cent confidence interval range of 15 to 29.

- **Density**

The maximum distance moved (MDM) by recaptured individuals between photo captures was between 2.1 km and 30.7 km (mean 8.4; ±SE 2.9). Based on HMMDM, the total sampling area was estimated to be 789.20 km^2 (±SE 50.98). Tiger density estimates based on estimate from model M_b in CAPTURE was 1.9 (±SE 0.36) individuals/100 km^2. Tiger density based on MLSECR analysis in DENSITY, was estimated at 0.75 (±SE 0.21) individuals/100 km^2.

DISCUSSION

- **Future monitoring and management**

The study produced the first abundance and density estimate for tigers from TMCC within India and Bhutan using capture recapture framework (Table 1). We estimated tiger density based on conventional approaches. The camera trapping study yielded 87 pictures of tigers comprising of 14 individuals in a total trapping effort of 5,955 trap night out of possible 6,592 trap nights. The four common tigers in TMCC were found to be sharing territory with each other. Based on the photo captured data the tigers were avoiding the southern boundary of MNP and the concentration was high towards the centre of TMCC indicating presence of good prey and the least disturb area. Further studies annually would provide more data on the movement patterns of these tigers. We recommend joint exercises, in form of monitoring as well as patrolling, to be carried out in TMCC to generate meaningful information for management purpose. Such joint exercises would also help in promoting the conservation initiatives in the landscape.

- **Diversity of mammals and relationship with tigers**

Apart from tigers, other carnivore species photographed included Leopard (including melanistic leopard), Clouded Leopard, Golden Cat (*Pardofelis temminckii*), Marbled Cat (*Pardofelis marmorata*), Leopard Cat (*Prionailurus bengalensis*), Jungle Cat (*Felis chaus*), Dhole (Cuon alpinus), Himalayan Black Bear (*Ursus thibetanus*), Sloth Bear (*Melursus ursinus*), Jackal (*Canis aureus*) and Civets. Herbivore prey species photo captured included Gaur, Wild pig (*Sus scrofa*), Sambar (*Rusa unicolor*), Barking Deer (*Muntiacus muntjak*), Goral (*Naemorhedus goral*), Serow (*Capricornis thar*), Asian Elephant and Porcupines. Such wide variety of mammal species in the landscape could be attributed to the varied geographical topography as well as the different vegetation type present in the landscape.

This could be the only landscape in the world with eight species of cats (felids) co-existing in the same area. The eight species being: Tiger, Leopard, Clouded Leopard, Marbled Cat, Golden Cat, Leopard Cat, Jungle Cat and Fishing Cat. All of them, except the fishing cat, were photo captured in the camera traps. The fishing cat, however, was sighted directly by one of our co-author in MNP, confirming its presence. Other important carnivores like dhole, sloth bear and black bear also share the same habitat with these cats making this landscape unique.

Table 1: Summary of camera trapping to estimate abundance and density of tigers from Trans-boundary Manas Conservation Complex

Total number of camera traps	102
Sampling occasion	64 days
Sampling effort (number of traps x sampling occasions)	5,955
Camera trap polygon area	436.37 km^2
Estimated buffer width (1/2 MMDM)	4.2 km
Effective sampled area	789.20 (±50.98)
Number of individual tigers captured	14
Estimated numbers of tigers in the sample area using model Mb	15 (95% CI: 15-29)
Estimated tiger density in sampled area using ½ MMDM	1.9 (±0.36) tigers/ 100 km^2
Estimated tiger density using MLSECR	0.75 (±0.21) tigers/ 100 km^2

We were able to determine the abundance and density estimates for leopards and clouded leopards from MNP. We photo captured 27 individually identified leopards comprising of 11 males and 13 females (three unidentified) and 16 individually identified clouded leopards comprising of four males and five females (seven unidentified), during the same survey period. The abundance estimate using M_h Jack-knife and Pledger model M_h was 47 (±SE 11.3) and 35.6 (±SE 5.5) respectively for leopards and 21 (±SE 6.6) and 25.03 (±SE 6.8) for clouded leopards. Density estimates using MLSECR was 3.4 (±SE 0.82) and 4.73 (±SE 1.43) individuals/100 km^2 for leopards and clouded leopards respectively (Borah et al., 2013 *in press*). We intend to determine the estimates of these species across TMCC soon.

Based on the higher abundance and density estimates for leopard and clouded leopard compared to tigers, we assume that there may be sympatric competition for food and space in predator guilds. It would be interesting to understand the intra-guild competition among these top predators and see how restricted habitat use and dietary overlap influence the abundance and distribution of tigers and other carnivores in TMCC and we would recommend such studies in future.

- **Monitoring method**

Photographic capture-recapture sampling is a reliable technique for estimating the abundances of tigers and other secretive animal species that can be identified individually from their natural markings. The present study further supports earlier studies (Karanth & Nichols, 1998; O'Brien et al., 2003; Karanth et al., 2004; Chauhan et al., 2005; Jhala et al., 2008, 2011; Sharma et al., 2009) on tigers using capture recapture framework. There was enough evidence for population closure assumption from the open Pradel models in MARK where recruitment and survival corresponding to immigration and fidelity was estimated. The overall model selection test ranked M_b (behavioural response to capture) as the best model in CAPTURE. Model M_b allows the animal to exhibit a behavioural response to capture and the model deals with the failure of the assumption that the initial capture does not affect subsequent capture probabilities. Based on our data we assume that the individual tigers in the TMCC may be exhibiting behavioural response. The probability of detecting an individual on at least one sampling occasion (Average p-hat) was 0.03, and comparable to that recorded for the studies undertaken in rainforest areas in South East Asian countries, Malaysia (Kawanishi, 2002), Sumatra (O'Brien et al., 2003) and other sites (Karanth et al., 2004). The current study at TMCC in an effectively sampled area of 789.20 km^2 (±SE 50.98) revealed a population estimate ($\hat{N}$) of 15 tigers with a standard error ($SE\hat{N}$) of 2.64, while the estimated density ($\hat{D}$ ($SE\hat{D}$)) was 1.9 (0.36) tigers/ 100 km^2 (based on ½ MMDM) and 0.75 (0.21) tigers/100 km^2 (based on MLSECR) .

Estimating densities from abundance estimates from closed population capture recapture models is largely based on observed animal movements (Borchers & Efford, 2008; Karanth & Nichols, 2010). The best approach of Maximum Likelihood is to use the spatial capture histories of camera traps in a likelihood-based density estimation framework (Borchers & Efford, 2008; Efford et al., 2009). Since the spatial likelihood approach does not depend on adding a buffer to the trapping polygon for estimating effective trapping area, the resultant estimates are least biased by trap layout and density (Efford, 2004). We, therefore at present, recommend park managers to utilize the densities estimated by MLSECR approach, in order to assess conservation intervention effectiveness for efficient management decisions. However, MLSECR remains inhibited by different assumptions relating to spatial use

Monitoring team on patrol in Royal Manas National Park, Bhutan © Royal Manas National Park, Bhutan

and animal distributions (Efford, 2004) in spite of latest developments for intrinsically estimating density. For studies on monitoring large carnivores, these assumptions needs to be taken into account based on the ecology of study species as well as the features of study area (Gray & Prum, 2011).

CONSERVATION IMPLICATIONS

For monitoring the success of conservation activities in various areas, baseline data on abundance and density estimates are crucial for various species of concern. Our estimates provide evidence that tigers in TMCC are effectively using the landscape along India and Bhutan. Further research studies in TMCC are of immediate need and would facilitate better understanding of all the major carnivore assemblages including that of tigers. Further, annual abundance and density estimation of tigers in TMCC will help monitor changes in populations and trends of these large carnivore population dynamics. The present study has also established a baseline for initiating a long-term monitoring programme for tigers and co-predators in TMCC. Whatever monitoring interventions are planned and implemented in future, it will be important to monitor the consequences for tigers and associated animal's abundance, and our study presents the baseline for such future comparison. Our results show that the TMCC is an extremely rich and productive ecosystem. Future studies should also address connectivity issues between landscapes in addition to continuation of long term monitoring of tiger populations and other associated species.

TMCC is vital for regional and global conservation of tigers in the wild. The region forms an indispensible corridor for the Terai-Arc Tiger Conservation Landscape between Terai regions (of Nepal and India) with landscapes in North eastern India, Myanmar and South East Asia. The future plan should evolve a lasting commitment by the two national governments of India and Bhutan for wildlife conservation and monitoring. Beside tiger and prey monitoring, immediate activities should include local-level exchanges and the formalisation of exchanges at a higher level. Future programmes should also concentrate on developing specific field of skills and practical training, to report poaching and illegal trade of species. These initial steps will inspire confidence to build partnerships and commitment to a long-term process of collaboration. Finally, efforts need to be made to develop a sustainable funding mechanism to ensure transboundary monitoring and co-operation between both the governments. In general terms, a strategy that consolidates and then expands the present achievements can be followed to strengthen the transboundary conservation initiatives.

ANNEX I

Identified tiger individuals from Transboundary Manas Conservation Complex

TM1M

TM2F

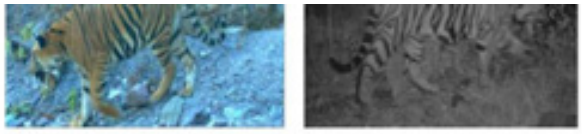
TM3F

TM4M

TM5M

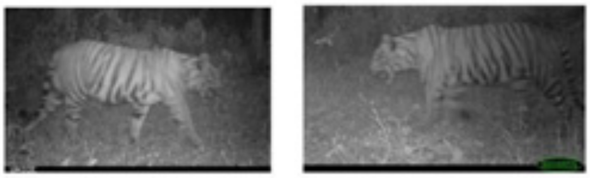
TM6F

TM7M



TM8M

TM9M



TM10F

TM11F

TM12F

TM13M

TM14M

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Note: The camera trapping in MNP was conducted as a part of All India Tiger Estimation exercise of Government of India, in collaboration with the National Tiger Conservation Authority (NTCA), Wildlife Institute of India (WII) and Assam Forest Department, and involved conservation organizations World Wide Fund for Nature (WWF) - India, Ashoka Trust for Research in Ecology and Environment (ATREE) and Aaranyak as partners, while in RMNP it was carried out for monitoring the tiger population by the Department of Forest and Park Services, RGoB, in collaboration with the Ugyen Wangchuk Institute for Conservation and Environment (UWICE) and the Bhutan Foundation. Supporting information on the study is available on request.

Panthera tigris tigris *© National Geographic Stock / Michael Nichols / WWF*

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The Transboundary Manas Conservation Complex (TMCC) team in RMNP Park Manager's office at Geluphu, Bhutan © WWF-India

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RESUMEN

El tigre *Panthera tigris*, se utiliza como especie emblemática o sombrilla para la conservación de la fauna y las áreas silvestres en muchas partes de Asia. Utilizamos cámaras trampa accionadas a control remoto y un marco de captura y recaptura dentro del Parque Nacional Manas en India y el Parque Nacional Royal Manas en Bután para estimar la abundancia y densidad de los tigres en el Complejo de Conservación Transfronteriza de Manas (TMCC). Se utilizó un total de 102 pares de cámaras trampa en tres rangos para cubrir un área de más de 400 km². Capturamos 87 fotografías de 14 tigres individualmente identificados (ocho machos y seis hembras), durante el período del estudio que abarcó 5955 noches de cámaras trampa. La población estimada fue de 15 (± SE 2,64) individuos con un 95 por ciento de intervalo de confianza de 15 a 29. La estimación de la densidad de los tigres mediante la utilización de ½ MMDM (distancia media máxima recorrida) y empleando el MLSECR (método de máxima probabilidad de captura y recaptura basado en datos espacialmente explícitos) fue de 1,9 (± SE 0,36) y 0,75 (± SE 0,21) individuos/100 km², respectivamente. El TMCC es un paisaje de crucial importancia para el futuro de los tigres, y la gestión eficaz de la biodiversidad debe ir más allá de los límites de las áreas protegidas y a través de fronteras políticas.

RÉSUMÉ

Le tigre (*Panthera tigris*) est utilisé comme une espèce emblématique ou parapluie pour conserver la faune et les aires sauvages dans de nombreuses régions d'Asie. Au sein du Parc national de Manas, en Inde, et du Parc national Royal Manas, au Bhoutan, nous avons utilisé des caméras-pièges pouvant être déclenchées à distance et la méthode capture-recapture, afin d'estimer le nombre et la densité des tigres dans le Complexe transfrontalier de conservation de Manas. Au total, ce sont 120 caméras-pièges qui ont été utilisées dans trois domaines, permettant ainsi de couvrir une zone de plus de 400 km². Nous avons ainsi pu prendre 87 photos de 14 tigres identifiés individuellement (huit mâles et six femelles), au cours de la période d'étude nocturne des 5 955 caméras-pièges. La population estimée était de 15 (±Erreur-type 2,64) individus, avec une fourchette d'incertitude de 95 pour cent de 15 à 29. Les estimations relatives à la densité des tigres, en utilisant ½ MMDM et l'analyse MLSECR étaient de 1.9 (±Erreur-type 0,36) et 0.75 (±Erreur-type 0,21) individus/100 km², respectivement. Le Complexe transfrontalier de conservation de Manas est un paysage crucial pour l'avenir des tigres, et il est donc essentiel que la gestion de la diversité biologique s'étende au-delà des limites des aires protégées et des frontières politiques pour être véritablement efficace.