STATUS OF TIGERS
IN BHUTAN

The National Tiger Survey Report

2021-2022

Department of Forests and Park Services
Ministry of Energy and Natural Resources
Royal Government of Bhutan

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List of Acronyms

AIC:	Akaike Information Criterion
BFD:	Bumthang Forest Division
BFL:	Bhutan for Life
BTC:	Bhutan Tiger Center
BTN:	Bhutan Tiger Number
BWS:	Bumdeling Wildlife Sanctuary
CFO:	Chief Forestry Officer
CITES:	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CMR:	Capture Mark Recapture
CTFM:	Camera Trap File Manager
DFD:	Dagana Forest Divsion
DoFPS:	Department of Forests and Park Services
FD:	Forest Division
GFD:	Gedu Forest Division
GTRP:	Global Tiger Recovery Program
GPS:	Global Positioning System
ID:	Identification
JDNP:	Jigme Dorji National Park
JKSNR:	Jigme Khesar Strict Nature Reserve
JSWNP:	Jigme Singye Wangchuck National Park
JWS:	Jhomotshangkha Wildlife Sanctuary
KPI:	Key Performance Indicator
m.a.s.l.:	Meters above sea level
MCMC:	Markov chain Monte Carlo
NCD:	Nature Conservation Division
MFD:	Mongar Forest Division
NGOs:	Non-Government Organizations
NFC-N-RMNP:	Northern Forest Complex-Namdhapha-Royal Manas
NSB:	National Statistics Bureau
NTS:	National Tiger Survey Report
Nu.:	Ngultrum (Bhutanese currency)
PAs:	Protected Areas
PFD:	Paro Forest Division
PGFD:	Pemagatshel Forest Division
PNP:	Phrumsengla National Park
PPD:	Policy and Planning Division
PWS:	Phibsoo Wildlife Sanctuary
QTRT:	Quick Tiger Response Team
RMNP:	Royal Manas National Park
SECR:	Spatial Explicitly Capture-Recapture
SFD:	Sarpang Forest Division
SJFD:	Samdrup Jongkhar Forest Division
SMFD:	Samtse Forest Division
SWS:	Sakteng Wildlife Sanctuary
TCL:	Tiger Conservation Landscape
TFD:	Trashigang Forest Division
THFD:	Thimphu Forest Division
TSFD:	Tsirang Forest Division
TRCs:	Tiger Range Countries
UNEP:	United Nations Environment Program
WCNP:	Wangchuck Centennial National Park
WFD:	Wangdue Forest Division
WWF:	World Wildlife Fund
ZFD:	Zhemgang Forest Division

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Department of Forests and Park Services
Ministry of Energy and Natural Resources
Royal Government of Bhutan

Foreword

It is an honour for me to write the foreword for this National Tiger Survey Report 2021–2022, which provides a comprehensive update on the status of tigers in Bhutan. The report provides detailed updates on the population status, geographical distribution, challenges, and opportunities in the conservation of tigers.

Tigers are an integral part of our cultural and natural heritage, and play a crucial role in maintaining the balance of ecosystems. The conservation of tigers has always been a priority for our leaders and policymakers. Even as we celebrate a thriving tiger population in Bhutan, tiger populations in many other regions have declined significantly in recent decades due to habitat loss, poaching, and loss of their prey species. It is, therefore, imperative that we act to protect these magnificent creatures and their habitats.

This Report is also a fruition of the hard work of numerous individuals and organisations towards this mammoth task. Setting up 1,201 camera stations in the wilderness of Bhutan is by no means an easy feat. I congratulate Bhutan Tiger Center for leading this massive endeavour to count our tigers which is both resource and manpower intensive. Our field divisions have done a great job in conducting the field surveys under treacherous conditions and it is a testament to how committed we are in our efforts to save this magnificent species.

This Report is based on extensive field surveys involving 307 field rangers, huge financial resources, and the state-of-the-art method in data analysis. It provides valuable insights into the status of tiger populations, their habitats, and the threats they face. It also highlights the progress made and the challenges that remain in conserving tigers and their habitats.

I hope this Report will be useful for all those working towards the conservation of tigers and their habitats and that it will inspire people to join the cause. I also hope that it will serve as a call to action for policymakers, organizations, and individuals to come together to ensure the long-term survival of tigers in our country.

Thank you for your interest in this Report and for your commitment to conserving tigers and their habitats.

Tashi Delek!

Lobzang Dorji
Director
DoFPS

Executive Summary

Large carnivores are endangered throughout their range across the globe. Loss of habitat and habitat fragmentation, prey depletion, and direct poaching to feed the illegal wildlife trade are the major causes driving them to near extinction. Although tigers (*Panthera tigris*) once roamed most Asian landscapes, they are now isolated and restricted to just 7% of their historical range and experiencing a rapid population decline. This warrants a concerted effort by different stakeholders including government agencies, Non-Government Organisations (NGOs), academia, developers, and farming communities to develop a multipronged strategy that could effectively halt further decline of tiger populations in the wild. Regular monitoring of the tiger population to provide the trend of how tigers are thriving and periodic nationwide tiger count to provide a snapshot of tiger status are of paramount importance for the long-term survival of tigers in the wild. The National Tiger Survey (NTS) 2021–2022 was conducted for the following objectives:

- To determine the current status of tiger populations, including their distribution, abundance, and trends, as a baseline for future monitoring and management.
- To identify the major threats to tiger populations, including poaching, habitat loss, and human-wildlife conflict, and prioritise action to mitigate these threats.
- To assess the country's commitment to maintaining a stable population of tigers in the wild.

Tiger populations have shown a modest increase as compared to 2014–2015 NTS, with a current estimated population of 131 tigers in the country, an increase of 27%.

The NTS Report 2021–2022 provides an update of the status of tigers in our country. The Report is based on extensive data collection using camera traps, field surveys, and data analysis of tiger populations.

The key findings of the report are as follows:

- The tiger population in Bhutan has increased from 103 in 2014–2015

(NTS-2015) to 131 in 2021–2022 (NTS 2023), which is an increase of 27%.

- The occurrence hotspots for tigers are Royal Manas National Park (RMNP), Jigme Singye Wangchuck National Park (JSWNP), Phibsoo Wildlife Sanctuary (PWS), Jigme Dorji National Park (JDNP), Bumthang, Dagana and Zhemgang Divisions with tiger density of more than two individuals per 100 km^2.
- The overall density of tigers in Bhutan for the whole country with an effective sampling area of 32,800 km^2 is 0.23 tigers per 100 km^2 with an average home range of 155 km^2 for female tigers and 498 km^2 for male tigers.

Bhutan as a source site for tigers in the region can not only reinvigorate the whole "Northern Forest Complex-Namdhapha-Royal Manas" (NFC-N-RM) conservation landscape but can provide critical linkages between the Terai-Arc landscape and Indo-Chinese tigers in Myanmar and further east. JSWNP and RMNP together with the Indian Manas Tiger Reserve is the most important and the largest protected area network and can support as many as 526 tigers.

Human-tiger conflicts remain the primary threat to tigers, and with increasing tiger numbers, conflicts will only get worse. Therefore, it is important to educate local communities on how to minimize conflicts and to provide support for those who suffer losses. Poaching and illegal wildlife trade also continue to pose a significant threat to tiger populations.

Conservation efforts have been successful in several areas, including increased law enforcement, community-based tiger conservation programs, habitat improvement, and protection of habitats. There is a need for further collaboration between government agencies, non-profit organizations, and local communities to effectively address the threats to tiger populations and conserve their habitats.

The National Tiger Survey Report 2021–2022 provides crucial information on the status and distribution of tigers in our country and highlights the challenges and opportunities for their conservation. The Report serves as a call to action for continued efforts to protect tigers and their habitats for future generations.

Acknowledgement

We extend our sincere appreciation and our deep gratitude to everyone who played a crucial role in the National Tiger Survey 2021–2022. This extensive project would not have been possible without the tireless efforts and contributions of many dedicated individuals and organizations.

We would like to thank the erstwhile Ministry of Agriculture and Forests, Royal Government of Bhutan for the necessary support and resources that enabled the successful completion of the survey. In particular, we would like to thank His Excellency Lyonpo Yeshey Penjor and Honorable Secretary Dasho Thinley Namgay for their unwavering commitment to tiger conservation and for being the driving force behind this project.

We would like to thank the Bhutan for Life for their generous financial support of Nu. 35.325 million, without which such a resource-extensive exercise would not be possible. We would like to thank UNEP's Vanishing Treasures Programme, funded by the Government of the Grand Dutchy of Luxembourg, for supporting this survey with Nu. 4.69 million. We would also like to extend our gratitude to WWF Bhutan for their support both in kind and financially.

We thank the Bhutan Trust Fund for Environmental Conservation and Bhutan Foundation for their support for the tiger conservation program.

We would like to recognize the efforts of the field offices and field staff, who conducted the survey with the utmost care and precision. Your commitment to collecting accurate data on tiger populations in the country was invaluable.

We express our gratitude to the local communities, who welcomed us into their homes and provided their support throughout the survey. Your cooperation and understanding were essential to the success of the project. We would aslo like to thank Dr. Kuenga Wangmo and Yuden from the Bhutan Ecological Society for their assistance with grammatical checks and language editing.

We would like to express our deep gratitude to everyone who contributed to the National Tiger Survey 2021–2022. Your efforts and dedication to wildlife conservation will have a lasting impact on the future of tigers in Bhutan.

Thank you.
Bhutan Tiger Center, DoFPS

CHAPTER 1

Introduction

1.1. Global Significance of Tigers

Tigers (*Panthera tigris*) are rare, elusive, and wide-ranging apex predators both feared and respected and thus, they are persecuted as well as worshipped as guardians of the wilderness (Seidenstic, 1996, Nyhus and Tilson, 2010).

Tigers are one of the largest and most endangered carnivores on the planet (Goodrich et al., 2015). They are often used as a flagship and umbrella species for the conservation of Asian landscapes (Wikramanayake et al., 1998, Barua 2011). Tigers once roamed in most of the Asian wildlands. Historically there were around 100,000 tigers at the turn of the last century, but today their number has plummeted below 4000 and they occupy a mere 7% of their historical range (Dinerstein et al., 2007, Goodrich et al., 2022). There are no other species in Asia that has received the attention of both scientists and conservationists like the tiger (Seidensticker 2010). The future of this charismatic predator is, however, not yet secured. A failure to not only slow down the drastic decline in population but reverse this trend will result in the loss of wild tigers and also bring about profound changes to ecosystem structures and dynamics throughout the Asiatic region. The main threats to tigers are poaching, habitat destruction and fragmentation, and depletion of their main ungulate prey species (Karanth and Nichols, 1995; Dinerstein et al., 2007; Sunquist, 2010).

The Global Tiger Recovery Program that was endorsed by the St. Petersburg Declaration on Tiger Conservation at the International Tiger Forum ('Tiger Summit') held in St. Petersburg, Russia, on November 21–24, 2010, has as one of its goals, the doubling of wild tiger numbers by the year 2022 (GTRP, 2011). Today, only 11 out of 13 tiger range countries harbour the last remaining tiger populations in the wild. These countries are also amongst the most densely populated by humans. The paradox of conserving wildlands and large carnivores while at the same time improving human welfare has generated much debate. Many tiger range countries are geared towards human welfare and socio-economic development and are experiencing profound economic growth fueled by open markets and globalization. In light of this, conservationists and practitioners have identified 76 Tiger Conservation Landscapes (TCLs) to prioritize and reinforce tiger conservation efforts in these 13 tiger range countries (Dinerstein et al., 2007, Sanderson et al., 2010). However, only 21% of the existing 76 TCLs are under some form of protected areas (PAs) and enormous pressures persist for the exploitation of natural resources such as gas, oil, and timber in the TCLs and PAs (Forrest et al., 2011) as well as new threats such as infrastructure development (Seidensticker 2015). Although habitat loss will continue to be the major threat to tiger survival, increasing poaching activities in the protected area also pose a serious threat to tiger populations (Wright 2010, Sharma et al., 2014). The insatiable market for tiger parts in China coupled with the appetite of people in Southeast Asia and North Eastern India for consuming anything that moves, create sad realities that render "empty forests" in these regions, reducing tigers indirectly (Redford 1992, Datta et al., 2008, Harrison, 2011, Velho et al., 2012).

In the Indian subcontinent, the conservation of the Royal Bengal tiger subspecies *(Panthera tigris tigris)* is at a critical juncture. The chilling revelation of extirpations of tigers in Indian tiger reserves designed specifically for tiger conservation has led to the growing realization that this subspecies is declining rapidly where they were thought to be thriving (Wright, 2010). The Bengal tiger's fate has never looked more uncertain. Recent studies reveal that half of the Bengal tiger population has disappeared in the last decade, largely due to massive forest destruction in India, as well as poaching (Wright, 2010). The northernmost tiger conservation landscape for Bengal tigers is the southern Himalayan foothills of Bhutan, Nepal, and India. This population is potentially separated from other populations in nearby Myanmar and South-East Asia, and there are growing concerns over connectivity between populations as population size in existing reserves declines. Bhutan, given its largely intact wild habitats, is key to ensuring the connectivity of tiger populations in the region.

1.2. Significance of Tigers in Bhutan

Tigers play an important role in the Bhutanese culture and religion. Manifesting as the wrathful Guru Dorje Drolö, in the eighth century, Guru Padmasambhava (also known as Guru Rinpoche) came from Singye Dzong riding on a flying tigress (believed to be his consort Nibni Trasgu Khydron (Dorji, 2022)) to Paro Taktsang (literally translated as the Tiger's Nest) in western Bhutan. It is believed that the Guru and his Khandro meditated in a cave where the main monastery is located today and the site is extremely sacred for Buddhists around the world even today (Figure 1.1).

The tiger is also considered to be one of four power animals, often referred to as the 'four dignitaries' associated with Tibetan Buddhism. Of the four dignitaries (Tiger, Snow Lion, Garuda, and Dragon), except for the tiger, the rest of these power animals are mythical creatures. The Bodhisattva Vajrapani is also depicted wearing the skin of a tiger, symbolizing the combination of yogic powers with the Buddhist association of the tiger with compassion and generosity. In addition, tigers are often painted on the walls of buildings, temples, and monasteries and also printed on Buddhist prayer flags along with the other power animals (Figure 1.2).

In Bhutanese culture, the tiger symbolizes power, strength, grace, and a creature that generates both fear and respect. In many remote villages, people still consider it a taboo to call the tiger by its name, "Tag", instead it is referred to as "Mamey Phama" (grandparents) in the Kheng region of east-central Bhutan, Phuga Mamey (mountain grandpa) in eastern Bhutan, and "Azha Tag" (uncle tiger) in the western region. These taboos are stronger among herding communities because of the fear that by referring to tigers by name, they are inviting the wrath of the tiger and harming their livestock.

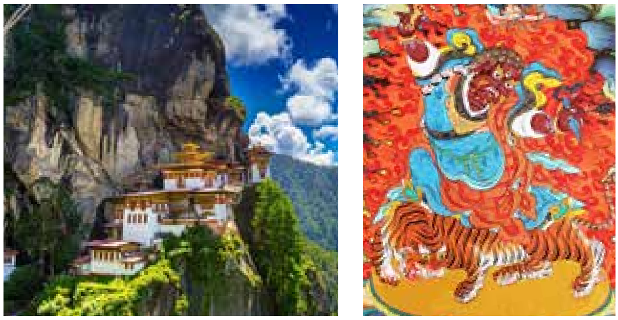

Figure 1.1: Paro Taktsang Monastery, popularly known as Tiger's Nest. The painting on the right is Guru Dorje Drolö, the wrathful manifestation of Guru Padmasambhava

Figure 1.2: Painting of tigers on Buddhist prayer flags, entrance of Dzongs and Monasteries, and on the walls of Bhutanese traditional houses

To many Bhutanese, tigers are sacred, they sanctify and consecrate our mountains.

To many Bhutanese, tigers are sacred, they sanctify and consecrate our mountains. People still believe that once a year, tigers descend to the valleys to drink water from the main rivers. There are numerous local myths and legends about tigers. One among these is the story from Laya, where it is believed that every year, tigers will make a pilgrimage to the peak of the tiger mountains. While we can dismiss these stories as myths, our recent camera-trapping work on tigers has shown that tigers do disperse from the lowlands to the high mountains and vice versa. Tigers from the Royal Manas National Park at an altitude of 200 meters above sea level were captured on camera traps in Jigme Dorji National Park at 4500 masl (UWICER, 2015).

Bhutan is a land of extremes, where snow leopards (*Panthera uncia*) and tigers co-exist in one landscape while also being a global biodiversity hotspot for other wild felids (Tempa et al., 2013). Bengal Tigers are known to occur in Bhutan in its sub-tropical jungles near the Indian plains to places above the tree line near the Tibetan border (Dorji and Santiapillai, 1989). The Royal Government of Bhutan is committed to conserving this species and has set aside more than 51% of the country's total land as protected areas in the form of national parks, wildlife sanctuaries, strict nature reserves, botanical parks, and biological corridors. Buddhist beliefs and ethos that respect all life forms have allowed tigers and their prey species to co-exist alongside humans and livestock (Tempa et al., 2019). Sound conservation policies from Bhutan's visionary kings and the sacrifices that communities made for the survival of these iconic creatures have enabled not only tigers but also other species to flourish in Bhutan, making it a safe haven for some of the most endangered species in the world. Further, poaching of tigers for wildlife trade is not a major threat in Bhutan unlike in other tiger range countries. As human populations grow and settlements expand, however, the tiger's survival is coming under threat due to habitat loss and increasing human-tiger conflicts.

Like developing countries elsewhere, in pursuit of economic development, forests are increasingly cleared for roads, hydroelectric dams, power transmission lines, mines, and commercial logging in Bhutan too. While the proponents of economic development projects claim that habitat disturbances will be temporary, the scale and intensity of development today are unprecedented. Moreover, there has been no consistent effort to evaluate the cumulative effects of development at the national scale in Bhutan (Kennedy 2002). Therefore, decisions and policies going forth must be based on sound scientific knowledge backed by empirical data.

Global initiatives to conserve tigers have helped in raising awareness of the precarious state of the species. The tiger summit in Russia in 2010 further reiterated the commitment of


Image of Snow Leopard and Tiger captured from the same camera station in JDNP from NTS 2021–2022 international agencies and tiger range countries to save this species. Through concerted efforts of international conservation agencies, NGOs, and tiger range countries, many programs are being initiated and implemented at the global as well as at regional levels to increase the number of tigers in the wild. Despite huge financial investments and efforts from these agencies and nations, tiger numbers continue to dwindle in most tiger-range countries. Without global and regional level initiatives being anchored to on-the-ground conservation actions at the local habitat level, it will be difficult to realise the global mission of preventing the extinction of tigers in the wild. In addition, to implement effective local-level actions and to have meaningful global dialogues, an understanding of how many tigers remain in the wild is crucial. It was with this objective that the fourth national tiger survey using remote camera traps was conducted in 2021–2022.

1.3. History of National Tiger Surveys

The Royal Government of Bhutan invested in counting tigers at the national level with the first assessment carried out by Dorji and Santiapillai (1989) using sign surveys reported by hunters and livestock herders. The second national tiger survey by McDougal and Tshering (1998) was carried out between 1996 and 1998 and used the pug-mark (track counts) method. The "pugmark" method was the common and widely used method for population estimates of large carnivores like tigers in the Indian subcontinent (Panwar, 1979, Hayward et al., 2002). The pugmark censuses were used as the standard monitoring method for Bengal tigers in the Indian subcontinent as recently as the early 2000s despite its lack of statistical rigour and high error rates (Karanth 1995, Karanth and Nichols, 2010). There was a growing need for more rigorous approaches to estimating tiger abundance and trends.

Breakthroughs in the last two decades have revolutionized the ability to non-invasively identify individuals using remote camera traps and estimate abundance with rigorous CMR methods (Karanth and Nichols, 1995, O'Connell et al., 2010, Mills et al., 2013). Ecologists started using remote cameras to estimate abundance for individually recognizable species (e.g., spots, stripes, marked with tags) using CMR methods (Karanth 1995, O'Connell et al., 2010, Kelly

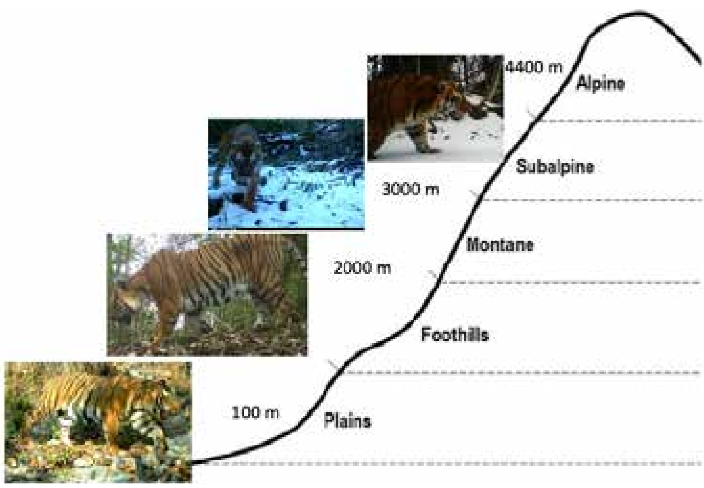

Figure 1.3: Distribution of tigers across elevational gradient of Bhutan

et al., 2012). Capitalizing on this method, Bhutan conducted its first tiger survey in JSWNP using remote camera traps between 2006-2007 (Wang and Macdonald, 2009). The long-term monitoring of the tiger population using remote camera traps, however, started in 2010 in RMNP (Tempa et. al, 2011) and expanded to JSWNP in 2013 (Tempa and Nawang, 2015).

The third National Tiger Survey of Bhutan 2014–2015 was conducted using remote camera traps and state-of-the-art statistical methods. It was carried out for the first time by an all-Bhutanese team. This was also in fulfilment of Bhutan's commitment to the 2010 Global Tiger Summit in St. Petersburg to use in-house expertise for its next national tiger survey. It demonstrated that Bhutanese biologists and foresters were no longer mere field assistants to ex-pat biologists but have the experience and expertise necessary to lead and conduct their surveys.

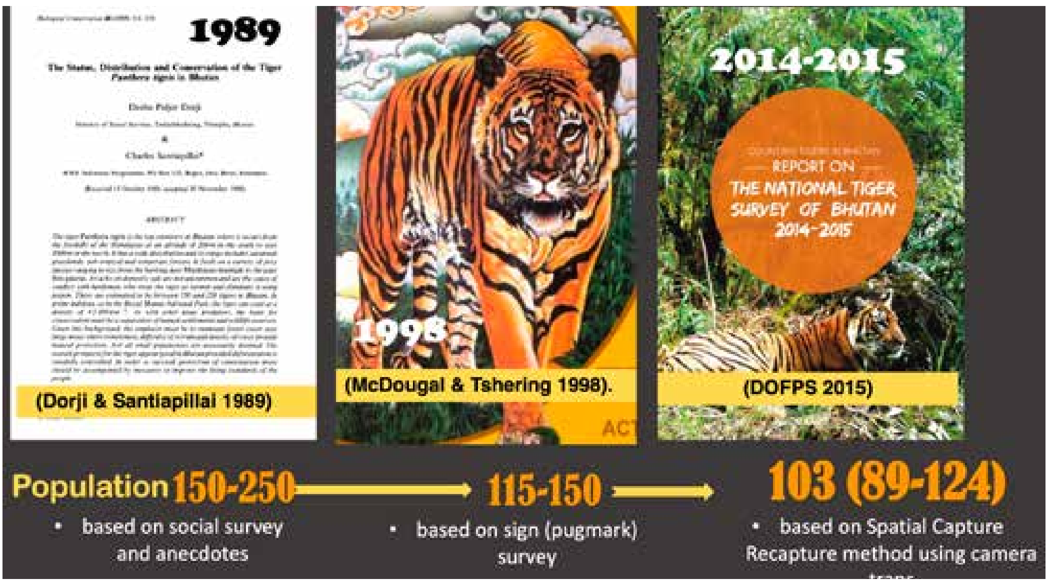

Figure 1.4: Past tiger surveys at the national level

1.4. Nation-wide Tiger Survey, 2021–2022

Building upon the success of the National Tiger Survey (NTS) of 2014–2015, the Department of Forests and Park Services (DoFPS) initiated many tiger programs which were reflected in mainstream development plans. A national tiger survey once every five years has become one of the key performance indicators for the DoFPS in the 12th Five-Year Plan of the government (RGoB, 2018). As a result of the establishment of the Bhutan Tiger Center (BTC), as a dedicated agency for tigers under the aegis of the DoFPS, the annual tiger population monitoring has been expanded to Bumthang and Zhemgang Divisions as well as the Phibsoo Wildlife Sanctuary in addition to the permanent tiger population monitoring sites in RMNP and JSWNP. While annual monitoring of tiger and prey populations is necessary for effective management and conservation interventions, the exercise can only be carried out on a small scale due to the enormous financial and human resource requirements. To provide a snapshot of the health and status of the tiger population in Bhutan, it was decided that a national tiger survey be conducted once every five years. The NTS 2021–2022 was conducted to guide conservation and management initiatives for the survival of tigers in the wild through a comprehensive understanding of the status of the tiger population in Bhutan. The objectives of the NTS-2021–2022 are as follows:

- To determine the current status of tiger populations, including their distribution, abundance, and trends, as a baseline for future monitoring and management.
- To identify the major threats to tiger populations, including poaching, habitat loss, and human-wildlife conflict, and prioritize action to mitigate these threats.
- To assess the country's commitment to maintaining a stable population of tigers in the wild.

Major breakthroughs in the last two decades have revolutionized the ability to non-invasively identify individuals using remote camera traps.

CHAPTER 2

Methods

2.1. Study Area

Bhutan with an area of 38,394 km^2 is a landlocked country bordered by the Tibet Autonomous Region of China to the north and Indian states of Arunachal Pradesh, Assam, West Bengal, and Sikkim to the east, south and west. It is situated in the biodiversity hotspot of the eastern Himalayas and lies between latitudes 26°N and 29°N, and longitudes 88°E and 93°E. Within an aerial distance of 170 km, elevation increases from as low as 90 m in the southern foothills to more than 7,500 m in the north. This region is a hotspot for wild felid diversity due to the significant altitudinal gradient that creates diverse climatic zones, ranging from wet sub-tropical in the south to alpine scrubland and permanent glaciers in the north (Tempa et al., 2013). Top predators like tiger, leopard, snow leopard (*Panthera pardus)*, and Asiatic wild dog (*Cuon alpinus)* roam these landscapes supported by diverse prey species like the guar (*Bos gaurus*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*), serow (*Capricornis thar*), hog deer *(Axis porcinus)*, Asiatic water buffalo (*Bubalus arnee)*, barking deer (*Muntiacus muntjak*), goral (*Naemorhedus goral*), blue sheep (*Pseudois nayaur*), and Bhutan takin (*Budorcas taxicolor whitei*). Additionally, Bhutan is home to a variety of threatened and endangered wildlife species like the tiger, Indian one-horned rhinoceros (*Rhinoceros unicornis*), Asiatic elephant (*Elephas maximus*), golden langur (*Trachypithecus geei*), red panda (*Ailurus fulgens*), hispid hare (*Caprolagus hispidus*) and critically endangered species like pygmy hog (*Porcula salvania*) and Chinese pangolin (*Manis pentadactyla*).

2.2. Survey Design

Using QGIS software, grid cells of 5x5 km were laid across the entire country (Figure 2.1). Based on the projected minimum home range size of female tigers in India, which is 15-20 km^2 (Karanth and Smith 2000, Sunquist 2010), a grid size of 5x5 km was chosen. Additionally, it was hypothesised based on past investigations in Bhutan (Wang and Macdonald 2009, Tempa et al., 2011, Tempa et al., 2019) that the territory size of female tigers in Bhutan was bigger than those reported in Nepal and India (Sunquist 1981, Karanth et al., 2004). Therefore, a cell size of 5x5 km enabled the installation of a minimum of two to three camera stations within a tiger's home range (Karanth and Nichols, 2002).

A total of 631 camera stations fell in the northern block and 583 in the southern block considering the favorability of the landscape and the logistics ease

After taking into account human settlements , and other unlikely habitats of tigers over 4,500 m elevations, 1,043 grid cells were selected (Figure 2.2). Finally 1,214 camera stations were identified (the grid cells in the lower foothills below 500 m had more than one camera trap station in a single grid cell) for the survey. These selected grids and identified camera stations were further segregated into northern and southern blocks. A total of 631 camera stations fall in the northern block and 583 in the southern block considering the favorability of the landscape and the ease of logistics (Appendix 1). These grids and camera stations were further divided by parks and territorial divisions before sending them to the respective field offices for their feedback and review (Appendix 2).

2.3. Training of the Field Staff for National Tiger Survey

Teams for the national tiger survey were formed in each of the 24 field offices following the finalisation of the grid cells and camera locations in 10 parks and 14 territorial divisions. A focal person was appointed for

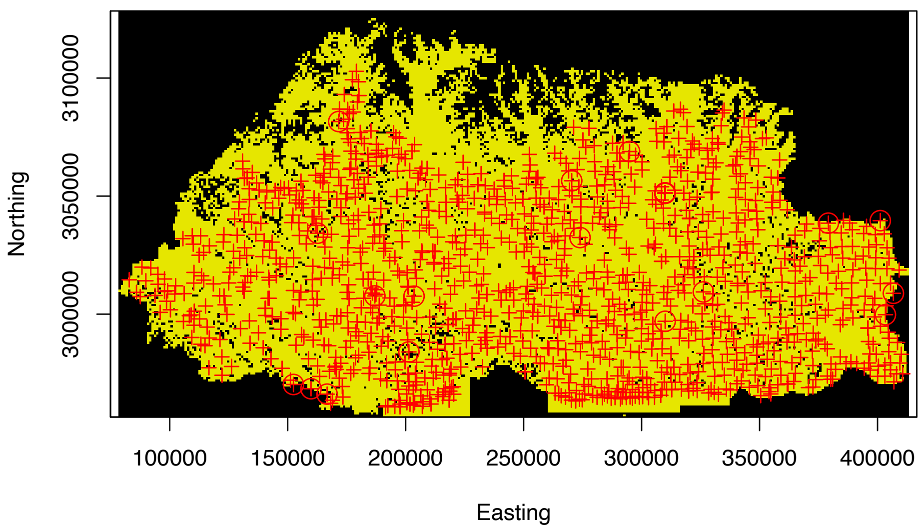

Figure 2.1: Map of habitat mask (state-space) after removing state-space (1,000 m) with elevation more than 4,500 m and settlement including agriculture fields. The yellow patches on the map represent good habitat and black patches represent non-habitat or unsuitable habitat

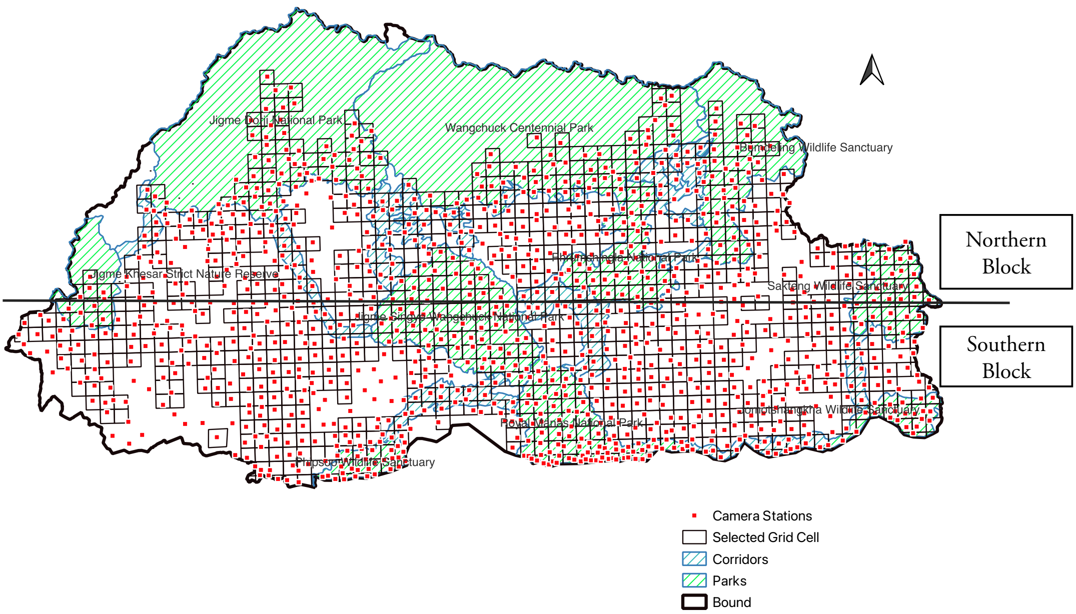

Figure 2.2: Map of Bhutan showing the selected grid cells and camera trap locations for the NTS 2021–2022

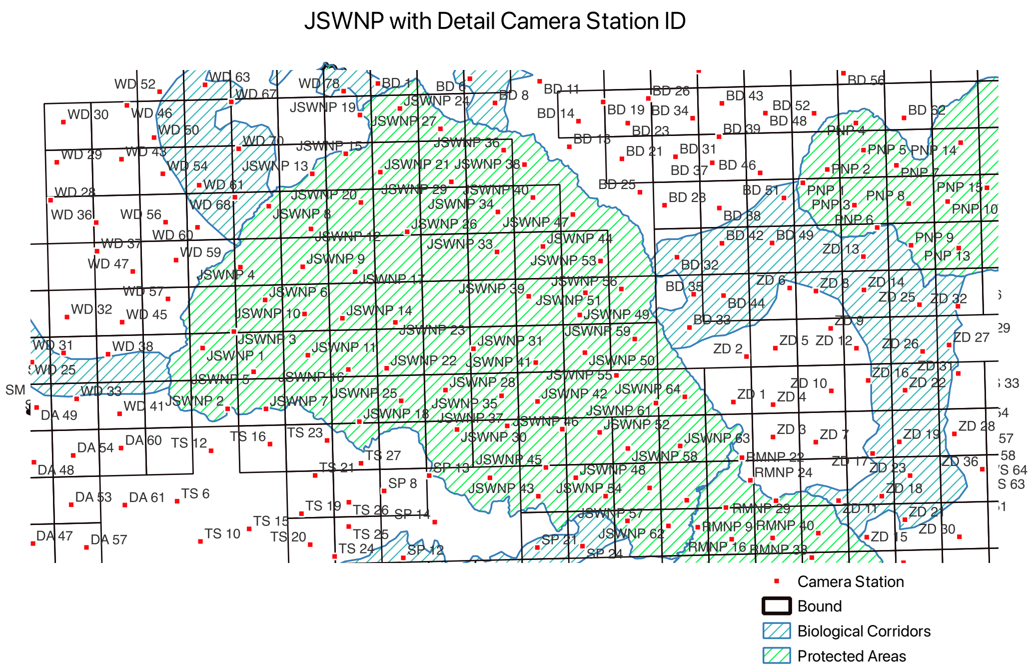

Figure 2.3: Close-up map of JSWNP showing details of the grid cells and the camera station numbers of NTS 2021–2022

each team to lead and coordinate the survey (Appendix 3). All field staff underwent extensive training beginning in August 2021 in order to standardise survey techniques based on the camera trapping protocol developed by the Bhutan Tiger Center (BTC, 2021).

2.4. Camera Trap Field Survey and Data Management

Grid cells were examined for potential tiger signs and tracks. Tigers are known to travel along preferred trials in a non-random manner like the majority of felids (Karanth and Nichols 2002, Kelly et al., 2011). Therefore, based on tiger signs and tracks within each 5x5 km grid cell, camera stations were opportunistically selected to maximise the capture of tigers. To prevent concentration of cameras at one location, the minimum distance between two camera stations was set at two kilometres.

At each camera station, two camera traps, one on each side of the trail or road, placed 5 m to 6 m apart, and at a height of 45 cm from the ground, were set up to photograph both flanks of a tiger for correct identification of individual tigers; tigers have unique pelage patterns on different flanks (Karanth and Nichols, 2002). Five different camera trap models, viz., Bushnell, CuddeBack, HCO-ScoutGuard, Reconyx (HC500 Hyperfire), and Panthera with a passive infrared system which is triggered by body heat as the animal passes in front of the sensor on the camera were used. A specific camera number was assigned to each camera trap, the locations were recorded using a Global Positioning System (GPS) device. And all other data,

including habitat type, ground cover, canopy cover, canopy height, signs of prey, and the presence of other carnivores were recorded.

Camera trapping for the NTS 2021–2022 was carried out from 11 October 2021 to 31 January 2022 in the northern block and 21 February 2022 to 30 June 2022 in the southern block. While efforts were made to monitor camera traps once a month, monthly monitoring could not be carried out in a few isolated and distant locations. After each monitoring round, all of the images were immediately downloaded to computers from the SD cards. Using the Camera Trap File Management (CTFM, Panthera) tool, images were divided into several species and given new names based on dates in order to create individual capture histories. In order to manually identify each tiger individual, its tail, head, and flank stripes were examined (Karanth, 1995, Schaller, 1967). For example, BTN_001 F was assigned to the first female tiger, BTN_002 M was assigned to the first male tiger, and BTN_003 U was assigned to the unidentified sex. The presence or absence of the scrotum was used to determine sex as male tigers have noticeable testicular protrusions. Tigers were divided into two age groups based on their level of independence from their mothers: adults and cubs (cubs are always recorded with their mothers). Daily capture was considered as one sampling occasion (1 sampling occasion is equal to 24 hours). In total 130 sampling occasions were recorded for the whole of Bhutan.

2.5. Spatially-Explicit Capture Recapture (SECR) Modelling

Although the density estimates are based on ad hoc methods of placing various buffer strips around the study area, the traditional mark-capture-recapture approach for closed populations offers a reliable estimate of the abundance of animals exposed to sampling. The spatially-explicit marked capture model also known as SECR model

Camera trapping for National Tiger Survey 2021–2022 was carried out from 11 October 2021 to 31 January 2022 in the northern block and from 21 February 2022 to 30 June 2022 in the southern block.

(Efford 2004, Borchers and Efford, 2008, Royle and Young, 2008, Royle et al., 2009b, Royle et al., 2011), explicitly models how an animal's distance from a detection device affects the likelihood that an individual in a population will be captured. The foundation of the SECR model is the presumption that each individual animal in a population has a home range and an activity center S_i which the animal roams about to meet its daily resource requirements. This is particularly relevant to carnivore populations, especially tigers as they are strongly territorial and maintain exclusive home ranges (Sunquist and Sunquist, 2002, Goodrich et al., 2015). Thus, the number of individual animals in the population (N) exposed to sampling is deduced by summing up the number of home range centers s_i. The relation between home range centers and population size is not simple and straightforward because the home range centers are not known and are random. The home centers are unobserved locations $S_i = S_1, S_2, S_3...S_N$, where S_i is the home range center of the tiger *i* (i.e., its Cartesian coordinates in 2-dimensional space $(S_{1i}, S_{2i}$)) is assumed to be distributed uniformly over some region *S*.

S_i~*Uniform S* Equation 2.1

The SECR model regards these activity centers as the outcome of a point process of the state space *S* (Gopalaswamy et al., 2012, Royle et al., 2013). Density is then derived as D = N/ area(S), where N is the parameter of the model and area(S) is the known area of the prescribed state-space (Royle et al., 2013).

Trap-specific encounter histories y_{ijk} were developed for individual $i=1,2,.....n_i$, in trap $j=1,2,....J$; sampling period=$1,2,...K$, where y_{ijk} = 1, if the individual tiger was captured at camera location *j* during sampling occasion k and y_{ijk} = 0, if the individual was not captured. Individuals captured at multiple camera locations for the same sampling occasion were allowed, but multiple captures of an individual in a particular trap during the same sampling occasion were considered a single capture. The model formulation of the observation process used by Gardner et al., (2010) and Russell et al., (2012) describes the encounter probabilities as a function of the distance between individual activity center and the trap as:

$$Pr\,Pr\,(y_{ijk} = 1) = 1 - exp\,(-\lambda_0 g_{ij}) \quad \text{Equation 2.2}$$

where ***exp*** is the baseline detection probability given that the camera trap is located exactly at the center of the home range of an individual tiger, $g_{ij} = exp\,(-d^2_{ij}/\sigma^2)$, where d_{ij} is the Euclidian distance between individual's activity center s_i and trap location x_j and σ is a scaling parameter (Gardner et al., 2010) was followed. This distance function is adopted from the theory of distance sampling (Buckland et al., 2001, Borchers and Efford, 2008).

Seven models were fitted to the data to see the effects of the different covariates on density estimates to test some of the a-priori hypotheses. The seven models were: (1) Model 1: basic model with no effect of the covariate, detection as the function of the distance between activity center and camera location; (2) Model 2: Effect of sex on the baseline detection (λ_0); 3) Model 3: Effect of sex on both baseline detection and the scale of activity distribution (σ) sex + σ_{sex}; 4) Model 4: Effect of sex + elevation; 5) Model 5: σ_{sex} + Elevation; 6) Model 6: Elevation; and 7) Model 7: sex + σ_{sex} + Elevation

2.6. Bayesian Analysis by MCMC

There are two main approaches to deriving SECR models; likelihood-based (Efford, 2004, Borchers and Efford, 2008); and Bayesian inferences (Royle et al., 2009a, Gopalaswamy et al., 2012, Royle et al., 2013). While there are advantages and drawbacks to both methods, the Bayesian approach has the following advantages: allows the direct use of probability to characterize information about unknown model parameters; posterior inferences are valid to any sample size which is crucial for ecological studies of rare and elusive animals, such as tigers, where sample sizes are often very small (Royle et al., 2013). Thus, in light of numerous recent research on large carnivores and tigers, the Bayesian approach to model analysis that makes use of data augmentation (Royle et al., 2007, Royle and Dorazio 2008, Gardner et al., 2010) was used to estimate the density of tigers in the study area (Royle et al., 2009a, Gopalaswamy et al., 2012, Sollmann et al., 2013, Goldberg et al., 2015, Proffitt et al., 2015, Xiao et al., 2016). In addition, as the Bayesian approach was used in the third National Tiger Survey of 2015, the same method was selected to ensure comparability of the results. Data augmentation was done by adding a large number of undetected individuals, each having all zero encounter histories, say M-n. It is assumed that this list of M pseudo-individuals includes the actual N individuals in the population as a subset. M (=300) was chosen since it was a sufficiently

In light of numerous recent research on large carnivores and tigers, the Bayesian approach to model analysis that makes use of data augmentation was used to estimate the density of tigers in the study area.

large number so as not to truncate the upper limit of the number of augmented animals. Furthermore, a uniform prior distribution was chosen from [0, M] on population size. The super population (M) and population size (N) are related by parameter ψ. ψ is the probability that an individual on the list of size M is a member of the population of size N that was exposed to sampling by the trap array (Royle and Young 2008).

The models were fitted using Markov Chain Monte Carlo (MCMC) methods in R (R Development Core 2022), using the "SCRbayes" package. The models were run for 50,000 iterations, with the first 20,000 iterations discarded as burn-in. To further narrow the chain and lower autocorrelation, every other iteration was skipped, leaving 15,000 iterations in the posterior sample. Utilizing the diagnostic tests in the "coda" package in R (Plummer et al., 2006), as well as by examining trace plots and histograms for each parameter, the convergence of the MCMC samples was evaluated. The mean, median, and 95% credibility intervals from these converged samples for the model parameters were computed.

2.7. Home Range Estimation

The implied tiger home range was calculated using a bivariate normal (Gaussian) PDF model for encounter probability as described by Royle et al., (2013). The estimated $\boldsymbol{\sigma}$ was used to calculate the 95% space using radius $r = \sigma x\sqrt{5.99}$ The 95% use area or the home range is the area around s which contains 95% of the movement outcomes calculated as $A = \pi r^2$. The value 5.99 is the α chi-square critical value on 2 df. If the encounter probability model is bivariate normal, as follows:

$$(x, s) = p_0 exp\,(-\frac{1}{2\sigma^2} \parallel x - s \parallel^2)$$

then $\parallel x - s \parallel^2$ will have a chi-square distribution with 2 df (Royle et al., 2013). The quantity $B(\alpha)$ that encloses $(1 - \alpha)$% of all realized distances is $B(\alpha) = \sigma\sqrt{q(\alpha, 2)}$ where $q(\alpha, 2)$is the α chi-square critical value on 2 df. Using this, the 95% home range from the σ estimate from all individuals as well as from the individuals who were captured from more than 3 trap locations was calculated. The home range sizes were estimated based on the maximum convex polygon for individuals captured at more than 3 camera locations.

Image of Clouded Leopard

Image of Asiatic Golden Cat with kitten

Image of Common Leopard

Image of Large Indian Civet

CHAPTER 3

Results

3.1. Camera Trap Results

Tigers were photo captured at 184 camera stations from eight protected areas and nine forest divisions (Figure 3.1).

There were 95 camera stations in the protected areas that recorded images of tigers; the biggest number came from RMNP with 37 sites, followed by PWS and JSWNP with 14 and 13 stations, respectively. The only protected areas that did not capture tiger images were JKSNR and BWS, while JWS and SWS each captured tiger images from one camera station. Of the 89 camera stations in the forest divisions that captured tigers, Bumthang division registered the highest with 34 camera stations with tigers, followed by Zhemgang and Dagana division with 19 and 14 camera stations, respectively. Mongar, Samdrup Jongkhar, Samtse, Sarpang, and Trashigang divisions did not capture any tiger images (Table 3.1).

From the survey effort of 68,854 trap nights, there were 6,611 still pictures and 59 videos of tigers captured from these camera stations. Some 4,934 images and 43 videos were used to develop the capture history, commonly known as an encounter data file (Royle et al., 2013), as seen in Annexure Table 1. Other images were discarded due to poor image quality. Individuals from two camera stations could not be ascertained and so only 182 camera stations were used for the analysis of tiger numbers. 103 adult tiger individuals were identified from these images: 44 males, 43 females, and 16 individuals whose sex could not be ascertained (Annexure 1). Cubs were not included in the analysis (Table 3.2). Individuals in the unidentified gender groups had 1–2 captures during the entire sampling period. Males, on average, were photo- captured six times (SE 1.16 range 1–44; median 6.63), while females had average photo-captures of 3 (SE 0.8 range 1–43; median 4) (Figure 3.1).

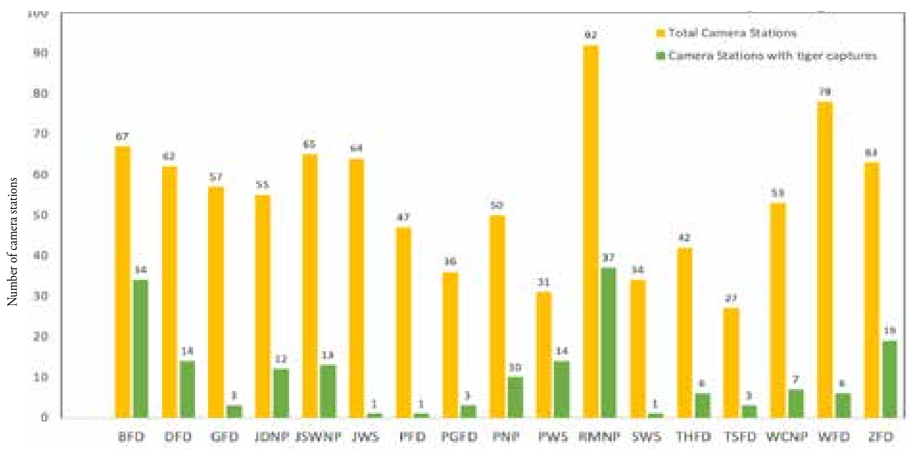

Figure 3.1: Total number of camera stations and number of camera stations that captured tigers

From the survey effort of 68,854 trap nights, there were 6,611 still pictures and 59 videos of tigers captured from these camera stations.

Twelve tiger individuals (seven male and five female adult tigers) were found to be common between seven forest divisions, and four protected areas (Table 3.2). These individuals showed great dispersal capabilities where males dispersed about twice farther as females based on detecting recaptured individuals across the landscape. For instance, BT_021M - an adult male tiger which was photo captured in Zhemgang Forest Division, Phrumsengla National Park, and Bumthang Forest Division had a detection polygon of 200 km^2. The average detection polygon for females was less than 50 km^2; the largest was 100 km^2.

Table 3.1: Total number of camera stations and tiger captures under each site in Northern and Southern block

Sl. No.	Site	Survey effort (trap nights)	Total stations	Total stations with tiger captures
Northern Block				
1	Thimphu Forest Division	4499	42	6(14%)
2	Paro Forest Division	4433	47	1(2%)
3	Bumthang Forest Division	4242	67	34(51%)
4	Sakteng Wildlife Sanctuary	3428	34	1(3%)
5	Phrumsengla National Park	2905	50	10(18%)
6	Jigme Dorji National Park	3600	55	12(22%)
7	Wangchuck Centennial National Park	4347	53	7(13%)
Southern Block				
1	Pemagatshel Forest Division	2755	36	3(8%)
2	Tsirang Forest Division	2336	27	3(11%)
3	Gedu Forest Division	2978	57	3(5%)
4	Phibsoo Wildlife Sanctuary	2929	31	14(45%)
5	Royal Manas National Park	7073	92	37(40%)
6	Jigme Singye Wangchuck National Park	3284	65	13(15%)
7	Jomotshangkha Wildlife Sanctuary	4414	64	1(2%)
8	Zhemgang Forest Division	5571	63	19(30%)
9	Dagana Forest Division	4712	62	14(23%)
10	Wangdue Forest Division	5348	78	6(8%)

Table 3.2: Number of tiger images and individual capture in each division. Recaptured tiger individuals in more than one field office are highlighted in bold texts

Sl. No.	Field Office	Number of tiger photos	Number of tiger videos	Number of individual tigers captured (including recaptures) in each site	Number of individual (excluding recaptures) tiger captured in each site	Tiger ID *(Annexure 1: Tiger Individuals)*
1	Thimphu Forest Division	85		3	3	BT_007M, **BT_008F, BT_009M**
2	Paro Forest Division	4		1	0	**BT_008F**
3	Zhemgang Forest Division	2259		14	12	**BT_020F, BT_021M,** BT_061M, BT_062M, BT_063F, BT_064F, BT_065F, BT_066F, BT_067F, BT_068U, BT_069U, BT_070F, BT_071U, BT_072F
4	Dagana Forest Division	341		4	4	**BT_001M,** BT_002F, BT_003U, BT_004U
5	Wangdue Forest Division	196		6	6	BT_026F, BT_027M, BT_028M, BT_029F, BT_030U, **BT_031M**
6	Bumthang Forest Division	723		21	20	**BT_021M, BT_063F,** BT_073F, BT_074M, BT_075M, **BT_076F,** BT_077M, **BT_078F, BT_079M,** BT_080F, BT_081F, BT_082F, BT_083F, BT_084U, BT_085M, BT_086M, BT_087F, BT_088M, BT_089U, BT_090F, BT_091U
7	Pemagatshel Forest Division	67		2	2	BT_012M, BT_013F,
8	Tsirang Forest Division	58		2	0	**BT_005M, BT_006M,**
9	Gedu Forest Division	62		2	1	BT_001M, BT_010U
10	Phibsoo Wildlife Sanctuary	320		7	6	BT_005M, BT_006M, BT_014M, BT_015F, BT_016F, BT_017M, BT_018M
11	Sakteng Wildlife Sanctuary	9		1	1	BT_011M
12	Royal Manas National Park	1240	57	29	29	BT_032M, BT_033M, BT_034F, BT_035F, BT_036F, BT_037M, BT_038M, BT_039M, BT_040M, BT_041F, BT_042M, BT_043F, BT_044M, BT_045F, BT_046F, BT_047F, BT_048F, BT_049U, BT_O50U, BT_051F, BT_052F, BT_053F, BT_054F, BT_055M, BT_056M, BT_057M, BT_058F, BT_059F, BT_060F
13	Jigme Singye Wangchuck National Park	425		8	8	BT_095F, BT_096U, BT_097M, BT_098M, BT_099U,BT_100F, BT_101M, BT_102F
14	Jomotshangkha Wildlife Sanctuary	3		1	1	BT_103M
15	Phrumsengla National Park	250		3	3	BT_019M, **BT_020F, BT_021M**
16	Jigme Dorji National Park	478		6	4	**BT_008F, BT_009M,** BT_022M, BT_023M, BT_024M, BU, BT5M
17	Wangchuck Centennial National Park	91		7	3	**BT_031M, BT_076F, BT_078F, BT_079M,** BT_092U, BT_093M, BT_094U
	Total	**6611**	57	117	103	




3.2. Tiger Abundance and Density from Bayesian SECR

All seven models were assessed to select the top models from the posterior estimates. Following the hypothesis testing method of Royle et al., (2013), the 95% credible interval of each posterior parameter estimate was compared. Proffitt et al., (2015) used the same method to select competing models in mountain lion (Puma concolor) studies in western Montana, USA. Sex-specific scale parameters (σsex) showed a positive effect of 95% credible interval that did not overlap; zero in all the models that had σsex as a covariate (Appendix 2). The top model used here estimated σ of 3.91 km (95% CI: 3.52–4.29 km) for females and 7.17 km (95% CI: 6.65–7.70 km) for males (Table 3.3). Sex as a covariate for baseline detection by itself showed no effect, a 95% credible interval overlapped with zero, however, in the presence of σsex as a covariate, it showed negative effects. This was expected because irrespective of sex if a tiger walked in front of a camera, it would be captured. The baseline detection probability λ_0 of tigers from the top model is 0.04 (95% CI: 0.029–0.056). The data augmentation parameters ψ, the probability that the augmented data belong to N for females was 0.33 (95% CI: 0.266–0.386) and 0.38 (95% CI: 0.292–0.48) for males, however, the 95% CI overlap for male and female suggests the difference is not significant (Table 3.3). The fit statistics Bayesian P value for the model was 0.89, which means that the model is under-dispersed. To evaluate if the lack of fitness is due to a large area of state space, the data for the Bumthang Division was subsetted and the top model ran using the same formulation and assumptions. The goodness of fit test resulted in a Bayesian p-value of 0.55 for this subset of data indicating that the models used were adequate. The top models were selected along with basic models (distance only) to compare the posterior estimates of density and abundance N (Table 3.3). The top model used gave an estimate of N, 131 (95% CI: 115–146) individual tigers, and a density of 0.23/100 km^2 (Table 3.3). The density map showed that tigers were distributed across Bhutan, not only in the PAs but outside of PAs too (Figure 3.2). The overall density for the whole study area was low, but it showed areas like JSWNP, Trongsa, RMNP, and Zhemgang having high tiger density with more than two tigers per 100 km^2.

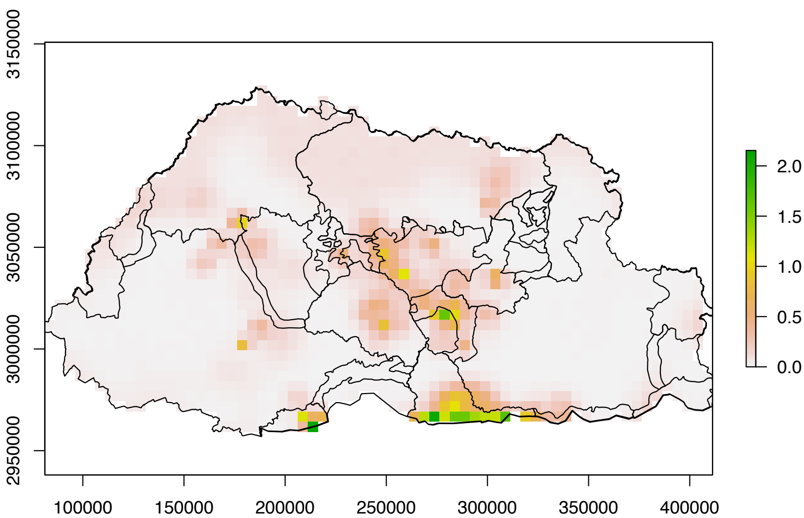

Figure 3.2: Map of Bhutan showing the posterior density estimate from the top model

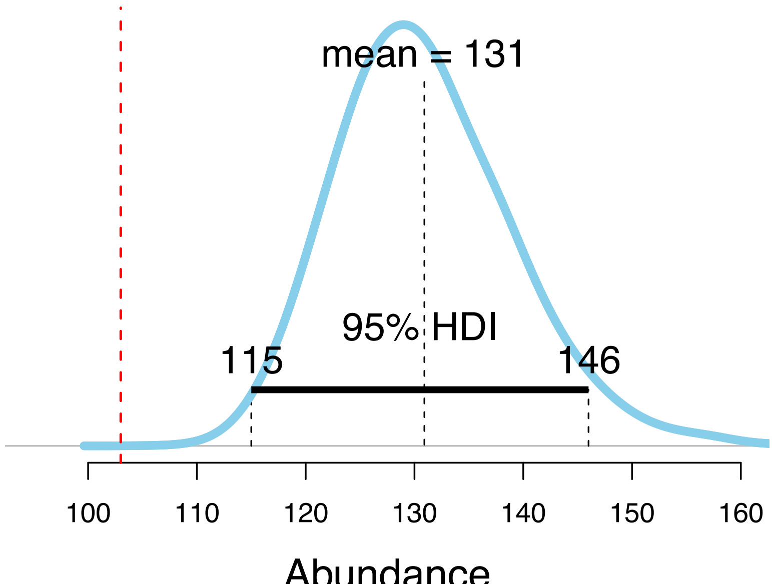

Figure 3.3: Graphs of posterior estimate of tiger abundance from the top model. The red dotted line represents the minimum live animals captured in the camera traps

Table 3.3: Posterior parameter estimates of the top model with sex as covariate for sigma

Parameters	mean	sd	l95	u95	MCEpc
bsigma	0.03	0.003	0.027	0.04	4.336
sigma	3.91	0.199	3.523	4.294	4.344
sigma2	7.17	0.269	6.645	7.695	3.552
lam0	0.04	0.007	0.029	0.056	5.45
psi	0.33	0.031	0.266	0.386	2.236
psi.sex	0.38	0.049	0.292	0.48	1.519
N	131	8.074	115	146	3.259
D	0.23	0.014	0.2	0.253	3.259

3.3. Maximum Likelihood and JAGs based SECR Estimates of Density and Abundance

For comparison, other methods were also used to run the models in addition to SCRbayes, both maximum likelihood-based (MLE) SECR (Efford 2022) and Just Another Gibbs Sampler (JAGS). The base/null models were run with no covariates and all three null models including SCRbayes null model gave similar estimates of density and abundance (Table 3.4, 3.5, and 3.6). However, using the sex covariates in MLE SECR gave a higher abundance of 180 individuals than SCRbayes models. The JAGs model was not run with sex covariate due to the requirement of a long computational time. The density estimate of 0.31 (95% CI 0.26–0.38) tigers per 100 km^2 and N of 180 individuals (95% CI 160–208) from MLE-based SECR was similar to results from SCRbayes. The scale parameter σ (the rate at which detection probability decreases) for female tigers was 4.92 km and for males was 6.01 km (Table 3.4), similar to results from the Bayesian-based models. The baseline detection g_0 (analogs to λ_0 of SCRbayes) for a male was 0.024 and 0.039 for a female (Table 3.5). This indicates that female tigers have higher baseline detection than male tigers. The results showed that elevation and human disturbances do not affect tiger density.

3.4. Home Range Sizes

The home range size calculated, following Royle et al., (2013) formulation using sigma, gave 287 km^2 for females and 967 km^2 for males. These home range size estimates are larger than expected home ranges, yet they are reasonable although Royle et al., (2013) advised against biological interpretations of home range area based on the sigma estimate from SECR.

Following Ringler et al., (2014) method of cumulative hazard rate: circular.r(detectfn=1, detectpar=list(sigma=1, z=4), hazard=TRUE), the 95% home range was estimated to be 155 km^2 for females and 498 km^2 for male tigers. This is consistent with the Maximum Convex Polygon (MCP) of 150 km^2 from more than

Table 3.4: Posterior parameter estimates from JAGS model (Null Model)

Parameter Estimates	Mean	SD	Median	L95	U95	Rhat	MCEpc
N	119	4.419	119	110	127	1	0.967
Omega	0.398	0.032	0.397	0.336	0.46	1	0.682
P_0	0.032	0.006	0.031	0.023	0.041	2.159	6.227
Sigma	6.369	0.558	6.362	5.535	7.225	2.742	6.569

Table 3.5: Posterior parameter estimates from SECRbayes Model (Null Model)

Parameter Estimates	Mean	SD	Median	L95	U95	MCEpc
sigma	7.195	0.22	7.195	6.755	7.63	4.712
lam0	0.022	0.002	0.022	0.019	0.026	4.783
psi	0.287	0.024	0.286	0.242	0.337	2.11
N	115	3	115	107	122	2.669
D	0.286	0.01	0.285	0.267	0.305	2.669

Table 3.6: Posterior parameter estimates from Maximum Likelihood (MLE) based Model with sex covariate for sigma and Lambda

Parameters	Estimate	SE. Estimate	Lcl	Ucl
FEMALE				
$Lambda_0$	0.034	0.005	0.025	0.044
Sigma	4.9	0.254	4.4	5.4
pmix	0.6	0.05	0.5	0.7
MALE				
$Lambda_0$	0.054	0.006	0.043	0.066
Sigma	6.2	0.24	5.8	6.7
pmix	0.40	0.05	0.31	0.50
E.N	180.8	18	148	220
R.N	180.8	12	160	208
D	0.31	0.03	0.26	0.38
ESA	32812.13			

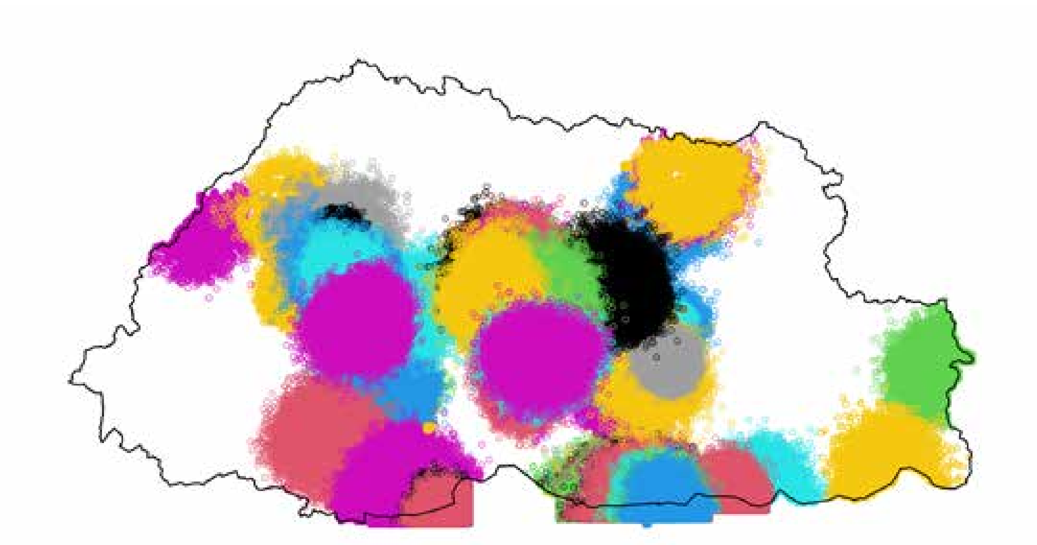

Figure 3.4: Individual Activity Center of captured tigers predicted by JAGs Model.

678 GPS locations of a radio-collared female tiger in Sephu, Wangdiphodrang. In addition, this is similar to MCP for those individuals that were captured from more than three camera stations, where the mean home range size of males is 169.37 km^2 (Range 17.33 - 547.76) and for females, it was about 70 km^2 (7.41-199.19) (Appendix Table 3). Although these estimates are higher than home range estimates from other prime tiger habitats in Nepal and India (Karanth et al., 2004), it is expected for rugged terrains and mountainous landscapes like Bhutan. One female and one male that had an MCP area of just 3.7 km^2 and 9.8 km^2 respectively, were not included and considered outliers because it was assumed that these individuals were transboundary and their range expanded across Bhutan's borders and hence, underrepresented. Locations of each individual's activity center are provided in Figure 3.4.

3.5. Tiger Recaptures from the National Tiger Survey 2014–2015

High tiger individual counts were reported from south-central and central Bhutan as compared to NTS-2014–2015. Notable amongst them were RMNP (N=29), followed by Bumthang FD (N=21) and Zhemgang FD (N=14). PWS, RMNP, Bumthang FD, and Zhemgang FD showed a significant increase in tiger captures from their baseline counts from the NTS 2014–2015. Dagana FD (N=4) reported tiger captures including breeding individuals for the first time. Pemagatshel FD (N=2) also reported two tiger individuals for the first time. On the other hand, Paro FD (N=1) showed a considerable decline in tiger capture from its baseline count of six tigers in 2014. Only six individual tigers of the NTS 2014–2015 could be correctly identified and considered as recaptured in NTS 2021–2022 from four field offices (Table 3.7). However, it does not mean that the rest of the tigers were lost or killed, although, from the database maintained at Bhutan Tiger Center, six individuals tigers of NTS 2014–2015 had been poached (two from JSWNP, one from Trongsa, one from Wangdue, and two from RMNP). We were also unable to compare many tiger individuals between the two surveys due to the poor quality of images (some just tails and legs) and the absence of sufficient images containing both flanks of tigers.

Table 3.7: Table showing tiger recaptures from the 2014–2015 national tiger survey

Field Office	Tiger individuals from first NTS 2014–2015	Tiger individual recaptures in the second NTS 2021–2022
Zhemgang Forest Division	17	3 (18%)
Jigme Singye Wangchuck National Park	12	1(8%)
Royal Manas National Park	15	1(7%)
Phibsoo Wildlife Sanctuary	1	1(100%)
Total number of unique tiger individuals		**6 (10%)**

CHAPTER 4

Discussion

4.1. Bhutan: A Source Site for Tigers

The current tiger population estimate of 131 individuals (95% CI: 115-146) for Bhutan is relatively large in one connected landscape. This is an increase by 27% from the NTS 2014–2015 where 103 individuals were estimated (DoFPS 2015). Compared to an estimate of 90 individual tigers (Tempa et al., 2019), there is a 40% increase in the tiger number in Bhutan. This further supports Tempa et al., (2019) assertion that Bhutan is a source site for tigers in the region. Bhutan's estimated number is substantively larger than the mean tiger population size of 50 individual tigers in 42 tiger source sites (Waltson et al., 2010). Only a few source sites such as Corbett and Nagarahole/Bandipur/Mudumula in India, Sundarbans in Bangladesh, Chitwan/Persa in Nepal, and Huai Kha Khaeng in Thailand have tiger numbers more than the current estimates from Bhutan. The tiger density estimate across Bhutan is 0.23 tigers per 100 km^2 (Table 3.3). This low density of tigers is the artefact of including the whole country as a state-space with an effective sampling area of 32,800 km^2 irrespective of whether tigers are there or not. Consequently, for the country, this density estimate is realistic and ecologically reasonable. The results however show where tigers are concentrated and point out that JSWNP, RMNP, PWS, Bumthang Forest Division, and Zhemgang Forest Division have as many as two tigers per 100 km^2 (Fig. 3.2). This is concurrent to the earlier findings from JSWNP and RMNP where tiger density was similar to the current results (Tempa et al., 2011, DoFPS, 2015, Tempa et al., 2019). The density estimate from these protected areas and forest divisions is comparable to some of the Indian national parks like Tadoba, Bhadra, and Chilla (Karanth et al., 2004, Harihar, 2005) but higher than Pakke (Chauhan et al.,

2006) and other south Asian countries such as Malaysia (Kawanishi and Sunquist, 2004), Sumatra (O'Brien et al., 2003, Wibisono et al., 2009), Lao PDR (Johnson et al., 2006), and Myanmar (Lynam et al., 2009). Wang and MacDonald (2009) reported a tiger density of 0.4-0.5 tigers per 100 km^2 from JSWNP, slightly higher than the present tiger density estimate for the whole country. The posterior parameter estimate of λ_0 0.025 and σ of 3.91 km (95% CI:3.5-4.3) for females and 7.2 km (95% CI:6.65 -7.7) for males is comparable to estimates from Bengal tiger studies in South India (Royle et al., 2009a) but lower than Amur tiger (Xiao et al., 2016). Therefore, our results show that tigers are spatially distributed across Bhutan and further north and the density seems to be higher in the central and interior of the country.

For a landscape that has an elevation gradient from 100 meters to 7,500 meters within an aerial distance of 170 km, the elevation is expected to have a strong influence on tiger density. Surprisingly, the results suggest otherwise and show no effect on tiger density. This is also evident from the multiple camera locations at higher elevations that captured more tigers than the camera traps from the valleys. This indicates that elevation is not a deterrent for tigers in Bhutan. Tigers, as a species, are very resilient and can adapt to a wide range of climatic conditions from tropical evergreen forests and swamps to cold tundra climatic conditions in the Russian Far East (Sunquist et al., 1999, Schaller, 2009). Most of the ecological studies on Bengal tigers were done in the plains of India and Nepal (Sunquist 1981, Smith et al., 1998, Karanth et al., 2004). In the scientific world, mountains were not considered a tiger-sustaining habitat and therefore accorded little priority for the conservation of tigers in the region. In the absence of systematic science-based studies in these mountains, the occurrence of tigers at higher elevations was dismissed as a few offshoots of main populations from the plains either as transient or overthrown old males. Bhutanese, on the other hand, had always believed that tigers are mountain creatures, and when asked where the villagers would find tigers, they often say 'in the mountains' instead of the valley bottoms. While other carnivores like brown bears, wolves, and lynx are known to select rugged, steep, and forested habitats elsewhere (May et al., 2008, Güthlin et al., 2011), not much is known about the tigers as this species was traditionally believed to be inhabitants of the plains. The results from NTS 2021–2022 show that elevation is not a strong deterrent to tiger density and agree with earlier studies in Bhutan (DoFPS 2015, Tempa et al., 2019, and Penjor et al., 2021). The presence of breeding tigers at high elevation and their spatial distribution throughout altitudinal gradients all support the notion that Bhutan is inevitably a source site for tigers in the region.

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4.2. Tigers and their Prey Species

Tigers in Bhutan are distributed from an elevation of 100 m in the southern foothills to the Himalayan mountain tops as high as 4,500 m above sea level (Figure 1.3). Tigers are not only residing there, but are also breeding. Four out of five tigresses that were captured in the camera traps with cubs were above 2,500 m above sea level. The abundance of large-bodied prey is a prerequisite for tigers to sustain and breed. The marginal small-size prey such as barking deer cannot sustain breeding females on their own (O'Brien et al., 2003, Karanth et al., 2004). While preys such as gaur were concentrated and limited in the lower foothills, they were also occasionally camera trapped at a staggering altitude above 4,000 m. Wild pigs on the other hand are abundant and widely distributed across Bhutan (Wangchuk 2004, Tempa et al., 2019). Wild pigs are considered the most notorious pests that continuously maraud crop-lands causing grievances to farmers in Bhutan. The positive aspect of this wild pig problem is that they sustain the high number of tiger populations in the mountains of Bhutan as wild pigs are the preferred prey species (Reddy et al., 2004, Lynam et al., 2009, Hayward et al., 2012). In 60 samples of supposedly tiger scats, 80 percent had pig hair in them. Thus, pigs could be the principal prey species of tigers which also support breeding females even at very high elevations. To see as many as 30-40 pigs in one group, at a single camera station is not uncommon in Bhutan. One plausible reason for such large numbers of wild pigs in these landscapes is that the cloud forests of the montane ecosystem are moist throughout the year; as a result of which, roots, acorns, insects and grubs are abundant and provide a continuous supply of food source for wild pigs. Crops like potatoes, corn, paddy and wheat also supplement their food supply. Other prey species such as sambar, serow, and barking deer are widely distributed and common in most parts of

Goral

Wild Pig

Sambar Deer

Barking Deer

Figure 4.1: Pictures of tiger prey species

Bhutan. These assemblages of prey base along with the abundant livestock in the mountains and forests support breeding tigers at such higher altitude which has not been known in the tiger conservation world before.

4.3. Human-Tiger Conflicts

While an almost 30% increase in tiger populations over a six-year period is a triumph for conservation efforts, this has also led to an increase in instances of human-tiger conflicts. There were instances in recent times where tigers were spotted in villages and populated areas both inside and outside of protected areas. Similar findings were also reported in the past where predation hotspots were found near the village peripherals (Sangay and Vernes, 2008; Rostro-Garca et al., 2016). It was also found from the collared female tiger in Sephu, that during the five months of constant monitoring, 95% of the time, the tiger was in the village areas making kills every two to three days, the majority of which were livestock. These findings also suggest that the tiger predation hotspots for livestock are also the areas where tiger densities are high. According to studies on livestock predation by tigers in Bhutan (Wang and Macdonald, 2006, Sangay and Vernes, 2008, Rostro-García et al., 2016, Letro & Fisher, 2020), humans are not a deterrent to tigers; at least not in Bhutan. In contrast to earlier research from other tiger habitats (Kerley et al., 2002, Linkie et al., 2006, Karanth et al., 2010, Barber-Meyer et al., 2013), Tempa et al., (2019) did not detect any notable negative influence of humans on tiger density estimates. This anomaly is not exclusive to Bhutan; a contentious research by Carter et al., (2013) demonstrated tiger and humans coexist at a fine scale level. It is important to note that Bhutan has a completely distinct geography, and the lowest population density with 20 people per km^2 (NSB, 2022). The majority of Bhutanese are Buddhists who do not hunt and abhor the slaughter of other living beings. Tigers are known to tolerate

Figure 4.2: Pictures of community based tiger conservation programs

human presence if enough prey and cover exist and as long as they are not persecuted and poached (Sunquist et al., 1999). Bhutan offers a good cover with more than 70% of the country being under forest cover. But there is a limit to how much livestock predation can be tolerated by Bhutanese farmers as people increasingly view tigers as a nuisance and a threat to their way of life.

Conservationists, farmers, and government agencies are becoming increasingly concerned about the threat that human-tiger conflicts pose to tigers in Bhutan. If tigers in Bhutan are to thrive, it is of utmost importance that human-tiger conflict is addressed. Although it is impossible to completely eliminate conflicts because humans and tigers are both apex consumers in the ecosystem and share a single connected landscape in Bhutan, it is possible to mitigate it to a tolerable level for both humans and tigers and ensure that neither their survival nor the livelihoods of farmers are compromised. Implementing strategies that deal with conflict's underlying causes, such as habitat restoration, wildlife management, and livestock management are crucial in this regard. As a result, there may be less pressure for tigers to enter areas where humans and their livestock are concentrated and confrontations between tigers and humans may be less frequent. Local communities must also be educated about conflict prevention strategies and how to help people who have suffered livestock losses. This can lessen the chance of further conflicts by fostering mutual respect and trust between humans and tigers (Figure 4.2).

To effectively address the human-tiger conflict in Bhutan, the root causes of conflicts should be addressed for which cooperation between government organisations, conservation organisations, NGOs, and local communities is necessary. Together, it is possible to create and put into practice efficient conservation strategies, improve local community knowledge and understanding, and offer assistance to individuals who have suffered losses.

On the contrary, there are also instances of tigers being poached by the local people (Figure 4.3). Every year, a tiger or two is killed by poachers with the objective to sell in the illegal wildlife trade markets. Such incidents are also triggered by limited livelihood enhancement opportunities for the farmers. Identifying better livelihood opportunities for farmers living in tiger landscapes coupled with regular awareness programmes is crucial. Regular enforcement through SMART patrolling

There are also instances where tigers are being poached by the local people. Every year, a tiger or two is killed by poachers with the objective to sell in the illegal wildlife trade markets.

Figure 4.3: Picture of a poached tiger skin from Trongsa

by the rangers and strong collaboration between enforcement agencies are essential in curbing the issue, before it becomes serious conservation threats.

4.4. Comparison of Tiger Numbers from NTS 2014–2015 to NTS 2021–2022

The increase in tiger numbers by 27% from 103 individuals in NTS 2014–2015 to 131 individuals in NTS 2021–2022 is a huge achievement. There is enough evidence to show that tiger numbers increased in RMNP (from 15 to 29), PWS (1 to 6), PNP (0 to 3), Bumthang Division (2 to 21), and Dagana Division (0 to 4) as compared to NTS 2014–2015. This indicates that the conservation initiatives of the DoFPS, such as, conservation through compassion programs, community-based tiger conservation initiatives, anti-poaching activities through SMART patrolling, and habitat improvement have been extremely successful. For species like tigers, an annual increment of 5% is possible provided their habitats are secured and other threats are removed (Harihar et al., 2014).

However, it is important to note that one of the reasons for increase in tiger population NTS 2021-2022 as compared to NTS 2014-2015 could also be due to increased survey efforts. In comparison to 726 camera stations that were functional in NTS 2014–2015, NTS 2021–2022 had 1,201 camera stations that were functional and widely distributed across the country (Figure 4.4).

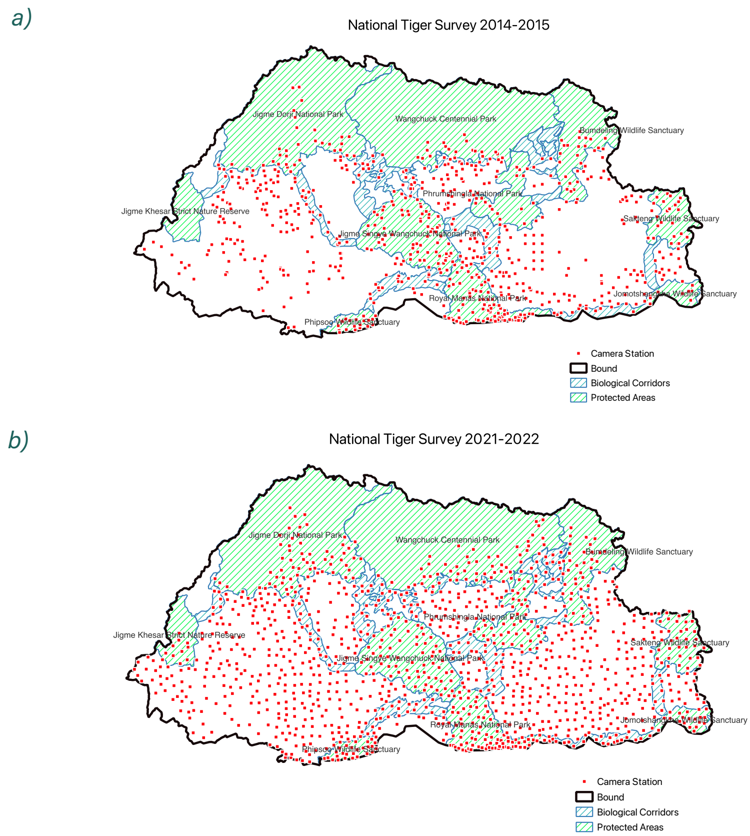

Figure 4.4: Map of Bhutan showing the camera stations for NTS 20142015 (a) and NTS 2021–2022 (b)

CHAPTER 5

Conclusion and Management Recommendations

5.1. Conservation Significance of Tigers in Bhutan

The conservation significance of tigers in Bhutan and their impact at the global stage are not exaggerations. Conserving tiger populations and their habitats, ensures ecosystems' health and resilience, support cultural and spiritual values, promote economic development, and mitigate the impacts of climate change. Tigers are apex predators and play a crucial role in maintaining a healthy and balanced ecosystem. By preying on herbivores and other species, they help to regulate populations and ensure the health of the ecosystem as a whole. Tigers are also indicators of the overall health of an ecosystem. A healthy population of tigers is a sign of a healthy and thriving ecosystem while declining tiger populations can indicate problems such as habitat loss, degradation, or pollution.

Tigers are also important for ecotourism, which can provide significant benefits for local communities and economies. By attracting tourists, ecotourism can create jobs and provide a source of income for local communities, helping to support conservation efforts and improve the well-being of local people.

An increase in tiger numbers by 27% over the past six years, almost a 5% increase annually, indicates that Bhutan's conservation efforts have paid off. Bhutan fulfilled its commitment to the Global Tiger Recovery Program to maintain viable tiger populations in the country. The 12th Five Year Plan KPI of the Ministry of Agriculture and Forests to increase the tiger number by 20% has been achieved. The Bhutan for Life's milestone to increase the tiger numbers in Bhutan by 20% has also been achieved. This is the fruition of sound policies of the Government, hard work and the commitments of rangers, and the support and investments of donors and partners.

5.2. Significance of Bhutan's Tigers in the Region.

This Report once again reaffirms that Bhutan is more important for tiger conservation in the region than previously thought or reported. A thriving tiger population in Bhutan is a beacon of hope for regional tiger conservation particularly in the eastern Himalayas. Bhutan is a hotspot for wild felids and harbours significant tiger populations of its own (Tempa et al., 2013, Tempa et al., 2019, Penjor et al., 2021). With a low density of people together with conservation-friendly policies and laws in place, Bhutan is an ideal source site for tigers in the region. Bhutan will not only reinvigorate the whole of NFC-N-RM with tigers, but also provide critical linkages between the Terai-Arc landscape and Indo-Chinese tigers in Myanmar and further east. JSWNP and RMNP together with the Indian Manas tiger reserve are the most important and largest protected area network and can support as many as 526 tigers (Ranganathan et al., 2008). This is what the late Dr. Alan Rabinowitz had to say:"Bhutan is like a heart in the region that will pump and reinvigorate tigers to the other regions" (BBC, 2010). This remark emphasis the importance of marginal tiger habitats where not much is known about tigers in such landscapes (Sunquist ,2010).

5.3. Conservation Challenges and Threats for Tigers in Bhutan

Conserving large carnivores is a complex and challenging task that requires a multi-disciplinary approach to address the various threats that these species face (Lute et al., 2018). Tiger conservation in Bhutan is not without challenges. If appropriate measures are not taken to address these challenges, the future of tigers in Bhutan remains uncertain. Some of the threats and challenges for tiger conservation in Bhutan are:

5.3.1 Human Tiger Conflict

Large carnivores like tigers play an important role in maintaining the balance of ecosystems, but they also come into conflict with human activities, which often results in their decline (Goodrich et al., 2015). One of the major challenges of conserving tigers in Bhutan is the conflict with humans. The livestock depredation by tigers causes huge economic losses for farmers and herders. In the Trongsa District alone, between July 2019-July 2021, a total of 560 livestock were killed by tigers (BTC, 2022). In response, people resort to harming and killing these animals illegally. Over the past few years, tigers have been seen in villages and settlements in broad daylight

posing serious threats to human lives. This often leads to political and social opposition to tiger conservation. Some people and organisations may be opposed to conservation efforts due to economic interests, or a lack of understanding about the importance of large carnivores in ecosystems. Human-tiger conflicts further exacerbate such opposition from different sections of society.

5.3.2 Habitat Loss and Degradation

Another challenge of conserving large carnivores is habitat loss. As human population continue to grow, natural habitats are being destroyed or fragmented, which can lead to a decline in large carnivore populations (Ripple et al., 2015). This is particularly true for species like tigers that have large home ranges. To address this issue, conservationists need to work with government agencies and other stakeholders to protect and manage large carnivore habitats, as well as to reduce the impacts of human activities, such as deforestation and road construction, on these habitats. Habitat for tigers seems to be better in and around the vicinity of villages. The abundance of the two most important prey species such as wild pigs and sambar deer is low in the mountains and deep forests where tigers and other wildlife are found. While tigers are using these mountain ridges to move from one place to another, there is very little that a tiger can eat in these mountains. Cattle and yak herders do not use the highland pasture any more. The bulk of wild ungulates like sambar and wild pigs exist near villages. This we believe is due to poor quality of habitat in the forests as grazing grounds are now overtaken by unpalatable shrubs and bushes. Thus, tigers move closer to villages, making easy kills of livestock further leading to human-tiger conflicts.

5.3.3 Poaching

Poaching is another major threat to tiger conservation, as their body parts are highly valued in the illegal wildlife trade. It is a matter of grave concern for the future of tiger if the number of tiger skins and body parts confiscated from the illegal market are any indication of the presence of tiger poaching in Bhutan. Over the past decade, the DoFPS confiscated more than 22 tiger skins. This trade not only results in the decline of tiger population, it also fuels the demand for wildlife products, which in turn drives further poaching. There is also evidence from camera traps from this survey of the presence of poaching in forests for other wildlife.

5.4. Management Recommendations

To address the above tiger conservation threats and to further secure the future of tiger populations in Bhutan, the following recommendations are made:

5.4.4 Human-Tiger Conflict Management

To turn local communities into tiger conservation stewards, the DoFPS needs to:

a) Strengthen measures in mitigating human-tiger conflicts through installing physical barriers/ corrals for livestock, providing compensation for livestock losses, and educating local communities about tiger behaviour and conservation importance; b) DoFPS needs to continue and expand the current Community based Tiger Conservation Fund to other gewogs. These schemes can help to mitigate the financial losses suffered by farmers and can help to reduce their opposition to tiger conservation; c) Establish a Quick Tiger Response Team (QTRT) in human-tiger conflict hotspot areas; d) Initiate and strengthen community based tiger conservation programs.

5.4.5 Habitat Protection and Improvement

Preserve and enhance tiger habitats, including biological corridors connecting different protected areas to enhance population dispersal from high-density sites to other locations. Cutting and burning of shrubs and bushes have been promoted as a method of grassland management for a number of reasons: (i) to prevent succession from grassland to forest; (ii) to prevent succession from invasive species like *Lantana* and *Eupatorium* which are less favoured by ungulates; and (iii) to provide ungulates with high quality forage as the grassland regenerates. This is based on the assumption that, once these habitats improve, wild ungulates will stay in the forest and thereby prevent them from coming into villages and raiding agriculture fields. This will also help to keep tigers in the forests.

5.4.6 Anti-poaching Efforts

To combat poaching, the DoFPS should continue to work with other law enforcement agencies to strengthen anti-poaching efforts and to reduce the demand for wildlife products. Additionally, strengthen education programs that raise awareness about the dangers of poaching and the importance of wildlife to reduce the demand for such products. SMART patrolling needs to be streamlined and mainstreamed as the main activity in PAs as well as in the divisions. The current program "Hunter to Hermitage Program" with BTC needs to be expanded to other areas.

5.4.7 Long-term Monitoring of Tiger Population

To better understand tiger ecology and behaviour and the threats and the impacts of conservation initiatives, annual monitoring of tiger population is important. This will provide information on recruitment, movement and how tiger populations respond to habitat improvement and other conservation initiatives. The BTC needs to continue the long-term monitoring of tiger populations in RMNP, PWS, JSWNP, Bumthang division, and Zhemgang division.

5.4.8 Education and Raising Awareness

Raise public awareness about the importance of tiger conservation and the need for human-tiger coexistence, especially among local communities. The DoFPS needs to engage with local communities, government agencies, and business leaders, to build support for tiger conservation. Through stakeholder partnership, develop solutions that meet the needs of both tigers and human populations, while also promoting the long-term health of ecosystems.

5.4.9 International Cooperation

Build and collaborate with relevant international agencies and NGOs in addressing transnational threats to tiger conservation, such as illegal trade in tiger parts and products.

Implementing these recommendations can not only enhance conservation of a healthy tigers population in Bhutan, Bhutan can become exemplary in tiger conservation approaches amongst the tiger range countries.

In conclusion, conserving large carnivores such as tigers is a complex and challenging task that requires a multi-disciplinary approach to address the various threats that these species face. By working together, government agencies, donors, and other stakeholders can develop strategies to protect tigers, reduce conflict with humans, and promote the long-term health of ecosystems. With continued effort and collaboration, it is possible to conserve tigers for future generations to enjoy and appreciate.

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Appendix Table 1: Sample of Tiger Encounter Data File

Sl no.	Southern Block	No. of Stations
1	DaganaFD	62
2	GeduFD	57
3	JSWNP	60
4	JWS	64
5	PemagatshelFD	36
6	PWS	31
7	RMNP	92
8	SamdrupJongkharFD	28
9	SamtseFD	34
10	SarpangFD	29
11	TrashigangFD	48
12	TsirangFD	27
13	ZhemgangFD	63
Total		**631**

Northern Block	No. of Stations
BumthangFD	67
BWS	45
JDNP	55
JKSNR	29
JSWNP	5
MongarFD	66
ParoFD	47
PNP	50
SWS	34
ThimphuFD	42
TrashigangFD	12
WangdiphodrangFD	78
WCNP	53
Total	**583**

Appendix Table 2: Sample of Tiger Encounter Data File

Trap_ID	ID	Occasion	Sex
111	1	72	MALE
112	1	88	MALE
112	1	104	MALE
118	1	40	MALE
119	1	74	MALE
119	1	94	MALE
121	1	80	MALE
123	1	69	MALE
125	1	23	MALE
125	1	95	MALE
150	1	53	MALE
193	1	91	MALE
206	1	93	MALE
123	2	85	FEMALE
127	2	31	FEMALE
127	2	85	FEMALE
144	2	84	FEMALE
151	2	25	FEMALE
151	3	25	FEMALE
151	4	25	FEMALE
986	5	62	MALE
989	5	61	MALE
998	5	99	MALE
646	5	75	MALE
649	5	59	MALE
651	5	87	MALE
651	5	96	MALE
652	5	56	MALE
653	5	97	MALE
654	5	32	MALE
658	5	4	MALE
658	5	45	MALE
…	…	…	…
…	…	…	…
…	…	…	…
…	…	…	…
360	100	52	FEMALE
354	101	52	MALE
354	102	52	FEMALE
391	103	60	MALE

Appendix Table 3: Details of number of tigers captured with cubs in each division

Sl. No.	Field Office	Number of tiger photos	Number of tiger videos	Number of individual tigers captured (including recaptures) in each site	Number of individual (excluding recaptures) tiger captured in each site	Adult male	Adult female	Adult unknown sex	Juvenile/ sub-adult	Cubs	Tiger ID *(Annexure 1: Tiger Individuals)*
1	Thimphu Forest Division	85		3	3	2	1				BT_007M, **BT_008F**, **BT_009M**
2	Paro Forest Division	4		1	0						BT_008F
3	Zhemgang Forest Division	2259		14	12	2	7	3	5		**BT_020F**, **BT_021M**, BT_061M, BT_062M, **BT_063F**, BT_064F, BT_065F, BT_066F, BT_067F, BT_068U, BT_069U, BT_070F, BT_071U, BT_072F
4	Dagana Forest Division	341		4	4	1	1	2	2		**BT_001M**, BT_002F, BT_003U, BT_004U
5	Wangdue Forest Division	196		6	6	3	2	1			BT_026F, BT_027M, BT_028M, BT_029F, BT_030U, **BT_031M**
6	Bumthang Forest Division	723		21	20	6	10	3		3	**BT_021M**, **BT_063F**, BT_073F, BT_074M, BT_075M, **BT_076F**, BT_077M, **BT_078F**, **BT_079M**, BT_080F, BT_081F, BT_082F, BT_083F, BT_084U, BT_085M, BT_086M, BT_087F, BT_088M, BT_089U, BT_090F, BT_091U
7	Pemagatshel Forest Division	67		2	2	1	1				BT_012M, BT_013F
8	Tsirang Forest Division	58		2	0	0					**BT_005M**, **BT_006M**
9	Gedu Forest Division	62		2	1			1			**BT_001M**, BT_010U
10	Phibsoo Wildlife Sanctuary	320		7	6	5	2		3		**BT_005M**, **BT_006M**, BT_014M, BT_015F, BT_016F, BT_017M, BT_018M
11	Sakteng Wildlife Sanctuary	9		1	1	1					BT_011M
12	Royal Manas National Park	1240	57	29	29	11	16	2	8	2	BT_032M, BT_033M, BT_034F, BT_035F, BT_036F, BT_037M, BT_038M, BT_039M, BT_040M, BT_041F, BT_042M, BT_043F, BT_044M, BT_045F, BT_046F, BT_047F, BT_048F, BT_049U, BT_O50U, BT_051F, BT_052F, BT_053F, BT_054F, BT_055M, BT_056M, BT_057M, BT_058F, BT_059F, BT_060F
13	Jigme Singye Wangchuck National Park	425		8	8	3	3	2	2	3	BT_095F, BT_096U, BT_097M, BT_098M, BT_099U,BT_100F, BT_101M, BT_102F
14	Jomotshangkha Wildlife Sanctuary	3		1	1	1					BT_103M
15	Phrumsengla National Park	250		3	3	2	1				BT_019M, **BT_020F**, **BT_021M**
16	Jigme Dorji National Park	478		6	4	4					**BT_008F**, **BT_009M**, BT_022M, BT_023M, BT_024M, BU, BT5M
17	Wangchuck Centennial National Park	91		7	3	1		2			**BT_031M**, **BT_076F**, **BT_078F**, **BT_079M**, BT_092U, BT_093M, BT_094U
	Total	**6611**	**57**	**117**	**103**	**43**	**44**	**16**	**20**	**8**	

Appendix I

Tiger Individuals from the National Tiger Survey 2021–2022

BT_001_M RIGHT

BT_001_M LEFT

BT_002_F RIGHT

BT_002_F LEFT

BT_003_U RIGHT

BT_003_U LEFT

BT_004_U RIGHT BT_004_U LEFT

BT_005_M RIGHT BT_005_M LEFT

BT_006_M RIGHT BT_006_M LEFT

BT_007_M RIGHT BT_007_M LEFT

BT_008_F RIGHT

BT_008_F LEFT

BT_009_M RIGHT

BT_009_M LEFT

BT_010_U LEFT

BT_011_M RIGHT

BT_011_M LEFT

BT_012_M RIGHT

BT_012_M LEFT

BT_013_F RIGHT

BT_013_F LEFT

BT_014_F RIGHT

BT_015_F RIGHT

BT_015_F LEFT

BT_016_F RIGHT

BT_016_F LEFT

BT_017_M RIGHT

BT_017_M LEFT

BT_018_M RIGHT

BT_018_M LEFT

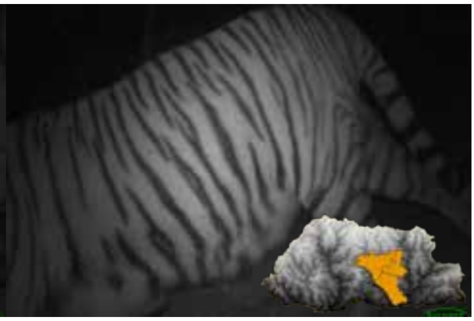
BT_019_M RIGHT

BT_019_M LEFT

BT_020_F RIGHT

BT_020_F LEFT

BT_021_M RIGHT



BT_021_M LEFT

BT_022_M RIGHT

BT_022_M LEFT

BT_023_M RIGHT

BT_023_M LEFT

BT_024_M RIGHT

BT_024_M LEFT

BT_025_F RIGHT

BT_025_F LEFT

BT_026_F RIGHT

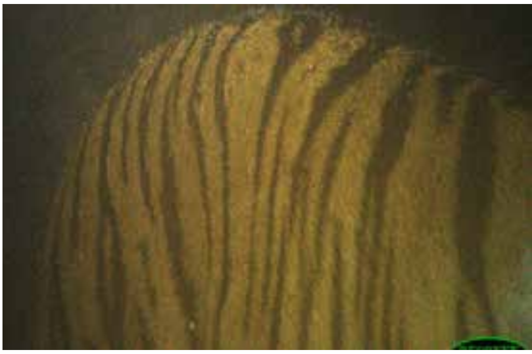
BT_026_F LEFT

BT_027_M RIGHT

BT_027_M LEFT

BT_028_M RIGHT

BT_028_M LEFT



BT_029_F RIGHT

BT_029_F LEFT

BT_030_U RIGHT

BT_031_M RIGHT

BT_032_M RIGHT

BT_032_M LEFT

BT_033_M RIGHT

BT_033_M LEFT

BT_034_F RIGHT

BT_034_F LEFT

BT_035_F LEFT

BT_036_F RIGHT BT_036_F LEFT

BT_037_M RIGHT BT_037_M LEFT

BT_038_M RIGHT BT_038_M LEFT

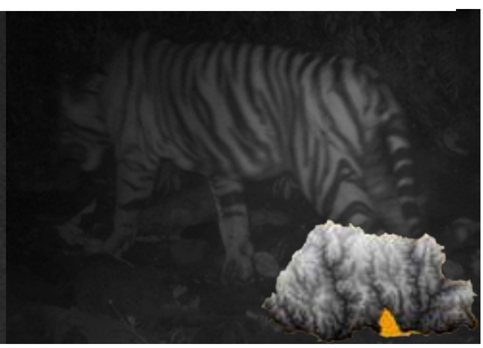
BT_039_M RIGHT BT_039_M LEFT

BT_040_M RIGHT

BT_041_F LEFT

BT_042_M LEFT

BT_043_F RIGHT



BT_043_F LEFT

BT_044_M RIGHT

BT_044_M LEFT

BT_045_F RIGHT

BT_045_F LEFT

BT_046_F LEFT

BT_047_F LEFT

BT_048_F RIGHT

BT_049_U RIGHT

BT_050_U RIGHT

BT_050_U LEFT

BT_051_F RIGHT

BT_051_F LEFT

BT_052_F RIGHT

BT_052_F LEFT

BT_053_F RIGHT

BT_053_F LEFT

BT_054_F RIGHT

BT_054_F LEFT

BT_055_M RIGHT

BT_055_M LEFT


BT_056_M RIGHT BT_056_M LEFT


BT_057_M RIGHT BT_057_M LEFT


BT_058_F RIGHT BT_058_F LEFT


BT_059_F RIGHT BT_059_F LEFT

BT_060_F RIGHT

BT_061_M RIGHT

BT_061_M LEFT

BT_062_M RIGHT

BT_062_M LEFT

BT_063_F RIGHT

BT_063_F LEFT

BT_064_F RIGHT

BT_064_F LEFT

BT_065_F RIGHT

BT_065_F LEFT

BT_066_F RIGHT

BT_067_F RIGHT

BT_067_F LEFT


BT_068_U RIGHT

BT_068_U LEFT


BT_069_U RIGHT

BT_069_U LEFT


BT_070_F RIGHT

BT_070_F LEFT


BT_071_U RIGHT

BT_071_U LEFT

BT_072_F RIGHT

BT_072_F LEFT

BT_073_F RIGHT

BT_073_F LEFT

BT_074_M RIGHT

BT_074_M LEFT

BT_075_M RIGHT

BT_075_M LEFT

BT_076_F RIGHT

BT_076_F LEFT

BT_077_M RIGHT

BT_077_M LEFT

BT_078_F RIGHT

BT_078_F LEFT

BT_079_M RIGHT

BT_079_M LEFT

BT_080_F RIGHT

BT_080_F LEFT

BT_081_F RIGHT

BT_081_F LEFT

BT_082_F RIGHT

BT_082_F LEFT

BT_083_F RIGHT

BT_083_F LEFT

BT_084_U RIGHT

BT_084_U LEFT

BT_085_M RIGHT

BT_085_M LEFT

BT_086_F RIGHT

BT_086_F LEFT

BT_087_F RIGHT

BT_087_F LEFT

BT_088_M RIGHT

BT_088_M LEFT

BT_089_U RIGHT

BT_090_F RIGHT

BT_091_U RIGHT

BT_091_U LEFT

BT_092_U RIGHT

BT_093_M RIGHT

BT_093_M LEFT

BT_094_U RIGHT

BT_095_F LEFT

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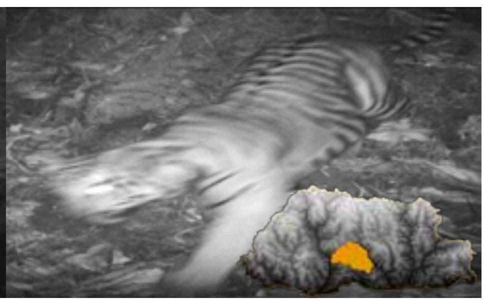
BT_098_F LEFT

BT_099_U RIGHT



BT_099_U LEFT

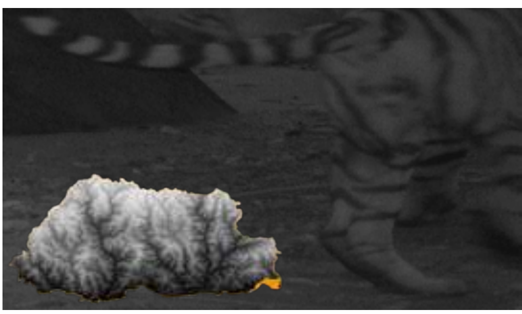
BT_100_F RIGHT

BT_100_F LEFT

BT_101_M RIGHT

BT_101_M RIGHT

BT_102_F RIGHT



BT_103_M RIGHT

BT_103_M LEFT

Appendix II

Pictures from the Field

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