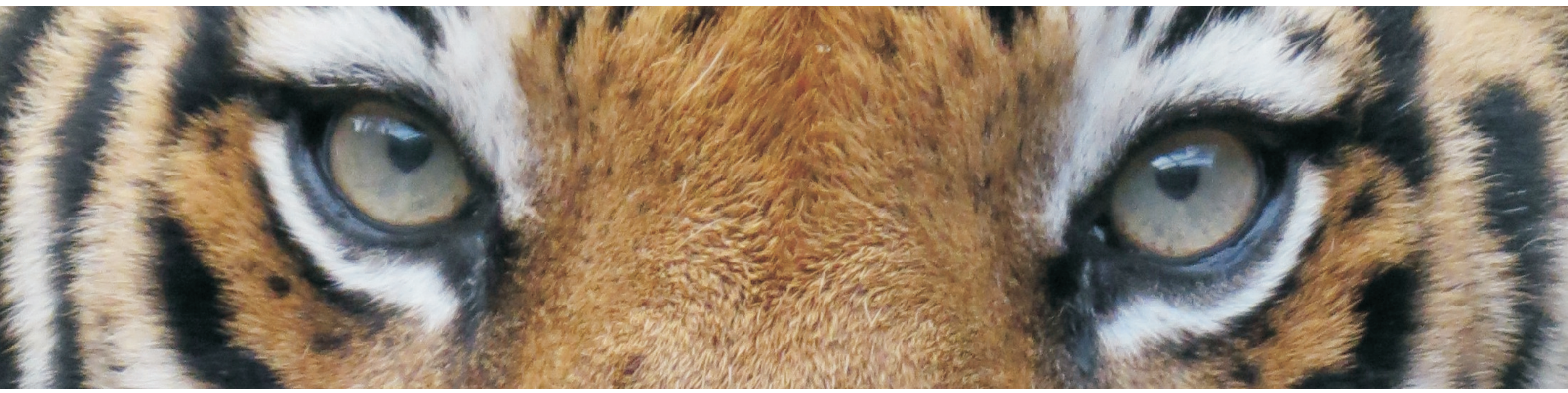
भारतीय वन्यजीव संस्थान
Wildlife Institute of India

National Tiger Conservation Authority

Patterns of Mortality in Free Ranging Tigers

(Technical Report 2016)



PATTERNS OF MORTALITY IN FREE RANGING TIGERS

Technical Report 2016

Wildlife Institute of India, Dehradun

National Tiger Conservation Authority, New Delhi

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Message

Director

Wildlife Institute of India

Tiger, the largest of all cats, is a wide-ranging species; whose numbers in the wild have declined as result of various anthropogenic activities in its distributional range. The drivers of tiger decline have traditionally believed to be restricted to habitat loss, poaching and fragmented population size; however, recent evidence indicates disease to be a new emerging threat to tigers.

The report 'Patterns of Mortality in Free Ranging Tigers' is a first study on this hitherto understudied aspect of tiger conservation. The report draws information from the existing database of mortality events maintained by NTCA and critically examines the various causal agents of tiger mortality in India.

The findings of the report indicate that anthropogenic factors are responsible for a large proportion of mortalities that take place in India. It also highlights the various infectious agents that are prevalent in tigers.

The report reiterates the need for detailed necropsy examinations based on laboratory support, maintenance of uniform reporting procedures and the necessity of a uniform database for identifying potential disease concerns in tigers besides documenting the patterns of mortality in tigers across landscapes in India.

I compliment the effort of the team in collating and interpreting the information from various sources and hope that their recommendations are reflected in actions at the field level.

(V.B. Mathur)

Message

Member Secretary

National Tiger Conservation Authority

Tiger, the national animal of India is a charismatic species inhabiting varied landscapes across the country. The species is facing imminent threats to its survival due to a range of anthropogenic factors. Conservation of tigers across their range assumes greater significance due to their keystone functions.

India has been at the forefront of tiger conservation since 1970s, the species today persists in 49 Tiger Reserves spread over five different landscapes in 18 range states and occupies 70244.10 sq. km.

The causal factors behind tiger declines across their range were earlier believed to be restricted to habitat loss and human induced mortalities. Recent studies have; however, established disease as an additional stressor.

'Patterns of Mortality in Free Ranging Tigers' a first of its kind study in India draws information from the database of mortality events maintained by NTCA and voices concerns for the need to study causal agents responsible for tiger fatalities in the country. The report reviews the available necropsy records and indicates that while human induced factors are responsible for a large proportion of the mortalities; infectious agents reported through laboratory examinations provide an insight into the likely diseases present in tiger populations.

The study stresses on the need for adherence to standardized protocols for reporting tiger mortality events. It further highlights the need for detailed necropsy examinations and laboratory confirmation, to have a uniform reporting procedure and a regularly updated database that provides a timely warning for managing disease outbreaks in tiger reserves across the country.

I commend the team for their efforts and exhort the field managers to reflect their effort in the reporting of tiger mortality events.

(B.S. Bonal, IFS)

Authors Preface

मा वनं छिन्धि सव्याघ्रं मा व्याघ्रा: नीनशन् वनात् |
वनं हि रक्ष्यते व्याघ्रौ: व्याघ्रान् रक्षति काननम् ||

महाभारत

Don't destroy the forest where tigers are living. Tigers should not get extinguished from the forests. Forest is protected by the tiger (People don't cut trees in the forest for fear of tiger) and by providing the place to hide, forest too protects the tiger!

\- Mahabharata

The numbers of tigers have drastically declined in recent past due to a variety of human induced factors. The anthropogenic drivers of tiger decline in association with the life history traits of delayed sexual maturity and long inter-birth intervals have resulted in their disappearing from otherwise suitable habitats. Tiger populations today exist in small pockets of their erstwhile habitats. Intensive conservation efforts have been initiated across their range based on outcomes of research on their biology, ecology, and behaviour. These studies have identified poaching and habitat loss to be the main drivers of population declines; however, they provide limited information on other factors causing morbidity and mortality in the species. The 'National Tiger Conservation Authority' had initiated a centralized database for all tiger mortality events reported in India to address this shortcoming.

We initiated a study to document mortalities of tigers in different landscapes across the country based on available mortality reports from the centralized database. The study is an attempt to focus on answering why, where and when tiger mortalities happened and the vulnerabilities with reference to gender and age, causal factors and location to assess effectiveness of the reporting process.

Our findings indicate that the number of mortality events reported were related to the number of tigers supported by individual landscapes and that males had a higher mortality rate than females with breeding age individuals to be the most susceptible age class. Intra-specific aggression and human induced mortalities were responsible for a large proportion of the cases reported. Deaths due to disease events were few in number; although a review of literature revealed the presence of a large number of infectious agents.

Our study indicates the necessity of uniform necropsy protocols, with adequate laboratory support and early reporting to assist management efforts in addressing factors leading to decline in tiger populations and aid in the process of disease surveillance and assessment of disease vulnerabilities of tigers.

(Authors)

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Contents

1 INTRODUCTION

INTRODUCTION

Large carnivore conservation assumes importance in view of the keystone species function performed by them. They directly or indirectly promote species richness by promoting resource facilitation and maintenance of trophic cascades. Their dependence on ecosystem productivity, sensitivities to perturbations in the ecosystems, and utilization of multiple ecosystem components (Noss et.al., 1996; Sergio et. al. 2008) makes them effective indicators of habitat quality.

As apex predators, tigers shape the ecosystems in which they live. Tigers are solitary and have large home ranges performing the role of 'umbrella' species providing space for a variety of other species to flourish. They prevent over-grazing by limiting herbivore numbers and maintaining ecological integrity.

The presence of viable populations of wild tigers is thus an indicator of the integrity, sustainability, and health of habitats they occupy.

(GTRP, 2011; Jhala, et al. 2015)

Tigers (*Panthera tigris*, Linnaeus, 1758), largest of all cats, are a wide-ranging species, endemic to the forests and grasslands of south and south-east Asia, the Russian Far East and north-east China (Forrest et al., 2011).

Eight tiger subspecies have been recognized based on their geographic distribution and morphology; the Bali tigers (*Panthera tigris balica*), Caspian (*Panthera tigris virgata*), Javan (*Panthera tigris sondaica*), Bengal (*Panthera tigris tigris*), Amur or Siberian (*Panthera tigris altaica*), Amoy or South China (*Panthera tigris amoyensis*), Sumatran (*Panthera tigris sumatrae*) and Indochinese (*Panthera tigris corbetti*). Molecular genetics based study has recognized existence of an additional subspecies; the Malayan tiger (*Panthera tigris jacksoni*) (Luo et. al., 2004). The Bali, Caspian and Javan subspecies are now extinct.

Their conservation however, poses a challenge due to the requirement of large, contiguous and relatively intact habitats. Tiger numbers in wild have drastically declined over the period due to a combination of adverse human activities that include, but are not limited to both habitat destruction and poaching. The global tiger population has increased in recent times owing to intensive conservation efforts; however, it is still considered low, with estimated breeding females reduced to approximately

1,000 individuals (Walston et al., 2010). The assessment of tiger status in 18 tiger range states of India revealed an estimated population of 2226 (1945-2491) tigers (Jhala et al., 2015).

TIGER ECOLOGY & BIOLOGY

Tigers are generally solitary, with adults maintaining exclusive territories (Sunquist et al. 1999). The reported home ranges may be as small as 20 km² as in Chitwan where prey is abundant to as large as 400 km² as in the Russian Far East that has low prey density (Sunquist and Sunquist 2002; Goodrich et al. 2015). Similarly, reported tiger densities range between 17 – 19 individuals per 100 km² (India's Kaziranga and Corbett National Park) to as low as 0.13–0.45 individuals per 100 km² (Russia's SikhoteAlin Mountains) (Jhala et al. 2011, Soutyrina et al. 2013). Adult female home ranges seldom overlap, whereas male home ranges typically overlap with 1–3 females, a common felid pattern of social organization. Male territory size is dependent on the assertiveness of the resident and adjacent territorial males, whereas the female's territory size is dependent on available food resources to meet demands of offsprings.

The tiger is an opportunistic predator hunting on a diverse prey base that includes sambar (*Rusa unicolor*), chital (*Axis axis*), barasingha/swamp deer (*Rucervus duvaucelii*), wild boar (*Sus scrofa*), hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjak*), nilgai/blue bull (*Boselaphus tragocamelus*), chousingha (*Tetracerus quadricornis*), chinkara (*Gazella bennettii*), black buck (*Antilope cervicapra*), gaur (*Bos gaurus*), wild buffalo (*Bubalus bubalis*) serow (*Naemorhedus sumatraensis*), porcupine (*Hystrix indica*), Hanuman langur (*Semnopithecus entellus*), rhesus macaque (*Macaca mulata*), bonnet macaque (*Macaca radiata*), peafowl (*Pavo cristatus*) and sometimes even calves of rhinoceros (*Rhinoceros unicornis*) and elephant (*Elephas maximus*). They have also been reported to kill other carnivores like sloth bear (*Melurus ursinus*), crocodile (*Crocodylus spp.*), scaly ant eater (*Manis spp.*) leopard (*Panthera pardus*) and dholes (*Cuon alpinus*). Apart from the wild prey, domestic cattle constitute a large part of their diet (Nowell and Jackson 1996; Hayward et al 2012; Srivastav etal., 2011). The natural history of the species is summarized in Table 1.1.

Table 1.1: Life history traits of tigers

Traits	Details (References)
Age of maturity	Females sexually mature at 3-4 years and male at 4-5 years (Mazák1981; Nowak 1999; Singh et al. 2014)
Mating system	Polyandrous mating system. Copulation frequent during mating (Sankhala, 1967). Mating induced ovulation (Sunquist and Sunquist 2002)
Life cycle breeding season	Any time of the year (Sankhala 1967; McDougal 1977; Karanth, 2001)
Life expectancy	20-26 years both in wild and in captivity (Mazák, 1981; Nowak, 1999).
Oestrous cycle	Comes into oestrus about every twenty-five days (Sunquist and Sunquist 2002).
Gestation period	Average of 104-106 days (Mazák, 1981; Nowak, 1999).
Litter size	Average of 2-3 (Mazák, 1981; Singh et al 2013).
Growth & development	Cubs are born with eyes closed that open after 6-14 days (Sludskij, 1953; Mazák and Volf, 1967; Mazák, 1981), nurse for 3-6 months, begin to move with mother at 5-6 months of age and are able to hunt by 11 months (Schaller, 1967). Males grow faster and the females stay back longer with the mother (Sunquist and Sunquist 2002).
Dispersal	Both sexes at two to three years of age (Schaller, 1967; Sankhala, 1967, 1978).
Inter-Birth interval	33.4±3.7 months (range 24–65 months) (Singh et al 2013).

BEHAVIOUR & SOCIAL INTERACTION

The tiger is a solitary predator exhibiting temporary association during mating and a prolonged association between mother and the offspring. While using regular travel routes, tigers constantly look for scent and visual evidence of other tigers. Fights and overt aggressive encounters are generally avoided; though these may occassionally result in serious fights, even culminating in death. Conflict between two tigers for defense of kills, cubs, home ranges and mating opportunities have been reported by Karanth, (2001); Sunquist and Sunquist (2002); Macdonald and Loveridge (2010).

DISTRIBUTION

Historically, tigers ranged across Asia, from Turkey in the west to the eastern coast of Russia (Nowell and Jackson 1996). The species presently inhabits the forests of South East Asia and are restricted to less than 7% of their historic range (Sanderson etal. 2006, Walston et al. 2010). Breeding populations survive in eight range countries namely Bangladesh, Bhutan, India, Indonesia, Malaysia, Nepal, Russia, and Thailand.

The subspecies found in India, the Bengal tiger (*Panthera tigris tigris*) lives in a wide variety of habitats, including the high altitude, cold, coniferous Himalayan forests, the steaming mangroves of the Sundarbans, the swampy reed lands, the scorched hills of the Indian peninsula, the lush wet forests of Northern India, and the arid forests of Rajasthan. They are also scattered across the subcontinent in Nepal, Bhutan, and Bangladesh which represent a varied ecological and demographic milieu (Johnsingh et al., 2010). Their distribution range in India across 18 states has been segregated into 5 landscape complexes with varying forest types (Figure 1.1).

1. **The Shivalik hills and Gangetic plains:** This landscape comprises of three parallel geological zones the Shivalik hills, the Bhabhar tract and the Terai plains. It traverses across

the political boundaries of Uttarakhand, Uttar Pradesh, and Bihar in India. Major forest types found in this landscape include moist Shivalik Sal forest, dry deciduous scrub and grassland, dry plains Sal forest, Northern dry mixed deciduous forest, West Gangetic moist deciduous forest and plantation (Champion and Seth 1968; Jhala et al., 2015).

2. **Central Indian & Eastern ghats landscape:** This landscape comprises of the semi-arid zone of Rajasthan, Central Indian plateau and includes parts of the Eastern Ghats and the Northern Western Ghats (Sahyadri) in Maharashtra. It traverses across the political boundaries of Andhra Pradesh, Chattisgarh, Jharkhand, Maharastra, Madhya Pradesh, Odisha and Rajasthan Major forest types found in this landscape include dry teak forest, moist peninsular Sal forest, dry deciduous scrub and grassland, *Anogeis suspendula* and *Boswellia* forest, southern dry mixed deciduous forest, northern dry mixed deciduous forest and southern moist mixed deciduous forest (Champion and Seth 1968; Jhala et al., 2015)

3. **Western ghats landscape:** This landscape traverses across the political boundaries of Goa, Karnataka, Kerala and Tamil Nadu. Major forest types include tropical evergreen forest, west coast semi evergreen forest, moist evergreen forest, slightly moist teak forest, moist deciduous forest, dry deciduous scrub forest, dry semi-deciduous forest and grasslands (Champion and Seth 1968; Jhala et al., 2015).

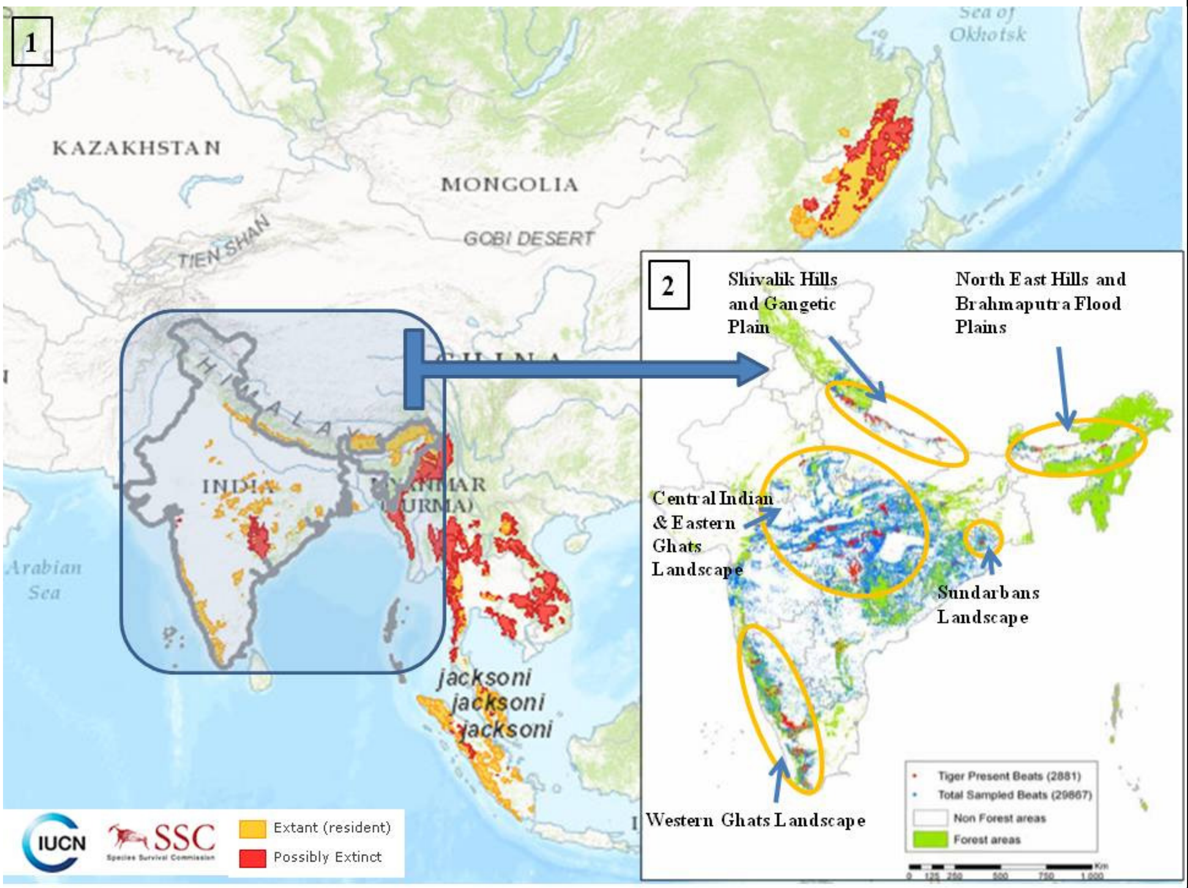


Figure 1.1: Distribution range of tiger (1: Goodrich *et. al*. 2015, 2: Jhala *et al*., 2015)

4. **North-east hills and Brahmaputra flood plains:** This landscape comprises of three zones; the Upper Bengal Dooars, the Brahmaputra flood plains and north-eastern hill region. Within this landscape tigers are reported to occur in the States of Assam, Arunachal Pradesh, Mizoram and northern part of West Bengal. Major forest types include east Himalayan moist mixed deciduous forest, east Himalayan mixed coniferous forest and Assam alluvial plains semi-evergreen forest (Champion and Seth 1968; Jhala et al., 2015).

5. **Sundarbans landscape:** It is the world's largest mangrove forest located at the estuarine phase of Ganges and Brahmaputra river system spreading across Bangladesh and India. The Sundarbans forest is classified under the sub-group 4B tidal swamp forests with subdivisions of mangrove type (4B/TS1 and 4B/TS2), salt water type mixed forest (4B/TS4), brackish type (4B/TS4) and palm swamp type (4B/E1) (Champion & Seth 1968).

THREATS AND STATUS

During the course of their evolution, large carnivores evolved traits that made them resilient to environmental disturbances. These include their generalist feeding habits due to variability in food availability; compensation by recruitment that addresses exploitation and dispersal for functional connectivity in disjointed habitats and colonization of vacant habitats (Weaver et al. 1996). Their innate resilience however has its limitations. Human activities continue to disrupt natural processes across a large portion of their habitats; the populations are thus rendered fragile. The cumulative impacts of these disruptions threaten their persistence (Weaver et al. 1996; Turner et al, 1993).

Tiger numbers in wild have drastically declined as a result of adverse human activities. In most countries, overhunting had been the driver of the decline in tigers and their prey (Karanth and Smith, 1999; Jhala et al., 2008; Walston et. al., 2010). Poaching for illegal trade in high-value tiger products remains a primary threat that has resulted in their disappearance from otherwise suitable habitats. Additionally, prey depletion, habitat degradation and linear development throughout its range have also caused serious declines (Goodrich et al., 2008; Jhala et al., 2015, Rangarajan 2006, Wikramanayake et al., 1998; Karanth, 2001). Tigers today are distributed heterogeneously and, except in the Russian Far East, restricted to small pockets, mostly in protected areas (Jhala et al., 2008; Walston et al., 2010).

In India, due to change in land ownership and forest use policy in the mid nineteenth century during British rule and again during the early years of India's independence a century later, large forests were cleared for timber and agricultural needs (Rangarajan, 1996). This change in land use combined with organized trophy hunting and bounty driven extermination resulted in severe decline, fragmentation and isolation of tiger populations throughout India (Narain et al., 2005). These small and isolated populations are also locally vulnerable to natural disasters, as exemplified by the catastrophic cyclone in 1988 in the Bangladesh Sundarbans, resulting in eight tiger deaths due to the calamity (Khan, 2004).

Threat to tiger survival also stem from the life history traits of the species as the long generation time makes them less likely to recover after population declines (Chapron et al. 2008); with even small changes in adult survivorship having serious consequences on their persistence, especially in isolated tiger populations. Retaliatory killing due to increasing intolerance from communities also presents an ongoing challenge for management to build local support for tiger conservation (Karanth and Gopal., 2005).

Table 1.2: Landscape level tiger population estimates (India)

Landscapes	Estimated number of tigers	
	2010	**2014**
The Shivalik hills and Gangetic plains	353 (320-388)	485(427-543)
Central Indian & Eastern ghats landscape	601 (518-685)	688(596-780)
Western ghats landscape	534 (500-568)	776(685-861)
North-east hills and Brahmaputra flood plains	148 (118-178)	201 (174-212)
Sundarbans	70 (64-90)	76 (62-96)
Total	1706 (1520-1909)	2226 (1945-2491)

Listed as Endangered on the IUCN Red List of Threatened Species (Goodrich et al, 2015), the species has suffered dramatic decreases in population and habitat, with current estimates of ~ 3500 tigers inhabiting 7% of their historic range (Sanderson et al., 2006; Dinerstein et al., 2007; Seidensticker et al, 2010). Tiger conservation and subsequent population recovery in India began during the 1970s with the creation of a number of protected areas (Tiger Reserves) under the Project Tiger network in 1973 (Tilson and Seal, 1987), and was further strengthened by India's comprehensive Wildlife Protection Act 1972.

Presented here are key issues pertinent to large carnivores from a study by Purvis et al. (2000) that reviewed extinction risk in declining populations.

Population declines coupled with a reduction in available habitats render the species more vulnerable to extinction (Gaston 1994) due to demographic stochasticity, local catastrophes, reduced adaptability and inbreeding (Brown, 1995; Lande, 1999). Species such as tigers that are at the apex of the food chain are more vulnerable to the accumulated effects of disturbance rather than species at the lower levels of the food chain (Diamond 1984; Crooks & Soule¨ 1999) due to their low reproductive output, a consequence of their natural history (MacArthur & Wilson 1967). Further the large body size of these species promotes their extinction as they exist at low population densities have slower turnover rates and require large home ranges (McKinney 1997) and they may be less tolerated and more persecuted by humans (Weaver, et al. 1996).

DISEASE AS THREAT

Until the pioneering work of Anderson and May (1979), the perception among most ecologists was that 'well-adapted' parasites do not harm their hosts. Lack of knowledge about pathogen diversity and susceptibility in wildlife was one of the main reasons for under appreciating infectious disease as a driver of host population dynamics (McCallum, 2012).

Recent declines in free-ranging populations of certain species due to infectious diseases have highlighted the potentially devastating effect of infectious diseases on carnivore population dynamics (Woodroffe 1999). Cleaveland and others (2007), as an outcome of their studies on outbreaks of Rabies and Canine Distemper virus (CDV) in Serengeti concluded that infectious disease constitutes a significant cause of mortality and can result in regional extirpation of species. Some other well documented examples include CDV in Serengeti lions (Roelke-Parker et al. *1996), CDV in wild black-footed ferret (Thorne and Williams 1988), CDV and rabies in Ethiopian wolves (Gordon et al., 2015; Johnson et al., 2010), Canine Parvovirus in Isle Royale wolf (Peterson* et al.*, 1998), and Tasmanian Devil Facial Tumor Disease (DFTD) in Tasmanian Devils (McCallum* et al.*, 2007). The above studies highlight the potential role of infectious diseases in causing significant morbidity and mortality in their carnivore hosts and undermine conservation efforts contributing to the endangerment of wildlife hosts.*

Published literature on captive tigers indicates that they are susceptible to an array of infectious agents, which are either native to or easily transmissible from domestic species. So far, mass mortalities have been reported in captive populations due to avian influenza (Keawcharoen et al.*, 2004), trypanosomiasis (Parija & Bhattacharya 2001), salmonellosis (Shilpa* et al.*, 2012), and canine distemper (Appel* et al.*, 1994). A study on mortalities in Amur tigers showed that besides the primary cause (poaching), about 8 to 13% of the mortalities in Amur tigers were due to canine distemper (Robinson* et al.*, 2015), implying an additional negative influence on tiger population dynamics (Gilbert* et al.*, 2014).*

REVIEW OF MORTALITY STUDIES IN CARNIVORES

Several ecological studies suggest that the rates of mortality are a major determinant of demographic processes in animal populations. Mortalities can substantially affect not only overall abundance and population persistence, but also the demographic traits such as age-structure and adult sex ratio (Caughley, 1977). Thus, information on the magnitude and causes of mortality can be of direct benefit to wildlife biologists as well as managers (Caughley and Sinclair, 1994).

Since identifying factors threatening wild populations requires an understanding of all possible threats or influences affecting population growth and persistence (Gabriel et al., 2015); baseline information, particularly on infectious diseases of relevance in large carnivore conservation is gaining increased importance.

Animals in wild die for several natural reasons including diseases, parasitism, starvation, predation and certain anthropogenic causes. Due to logistic difficulties in quantifying mortality events including rarity of circumstances wherein the events can actually be observed; robust empirical data on mortality rates are only available for relatively few free-living populations. Further, a review of literature carried out to assess the causes of mortality in carnivores across the world showed that most studies focused on individual landscapes with a probable reported bias towards radio-collared animals (Taylor et al. 2002; Goodrich et al. 2008). However, such information on mortality proved to be a valuable asset for management interventions aimed at conservation of the species. Patterns of mortality in select carnivores are summarized in table 1.3.

Table 1.3: Reported mortality causes in select carnivores based on published information.

Mortality cause	**Species**					
	Florida Panther (*Puma concolor coryi*)	Wolverine (*Gulo gulo*)	Grey Wolf (*Canis lupus*)	Brown bears (*Ursus arctos*)	Eurasian lynx (*Lynx lynx*)	Amur Tiger (*Panthera tigris altaica*)
Intra-specific aggression	19%	--	--	16%	10.59% (Classified as natural by the authors)	15% (Classified as natural by the authors)
Inter-specific aggression	--	17.74%	5%	--		
Infectious disease	3%	--	25%	1%		
Non-infectious disease	--	--	--	2%		
Nutritional disorders	--	29.03%	%	3%		
Congenital disorders	1%	--	5%	--	--	--
Vehicular trauma	36%	4.83%	35%	5%	4.63%	8%
Poaching	10%	35.48%	25%	53%	41.72%	64%
Undetermined	18%	12.90%	5%	7%	43.04%	13%
Source	Taylor et al., (2002)	Krebs et al., (2004)	Mörner et al., (2005)		Andren et al., 2006)	Goodrich et al., (2008)

RELEVANCE OF NECROPSY PROCEDURES & STUDIES

As direct assessment of factors causing mortality are difficult to perform; a review of the necropsy records may provide critical in-sight into mortality patterns (Batista et al., 2014). Necropsy is the basic and essential step that could help in establishing, proving, confirming and in certain cases even clarifying or modifying a diagnosis (Peixoto & Barros 1998). It allows one to identify the morphological, ecological, and pathological aspects of a mortality event, enabling these data to be correlated with quality of life and the environment (Almeida et al., 2005). Additionally, clinical and pathological studies produce substantial data from necropsies, which could guide the development of appropriate wildlife management programs (Batista et al., 2014). Studies carried out by Taylor and co-workers (2002) and Forrester & Wittmer (2013), on specific causes of mortality in Florida panthers and mule deer, black tailed deer in North America respectively based on necropsy reports, revealed potential risk factors that may be impacting the populations and helped focus management efforts aimed at addressing threats.

Except for a few studies (Goodrich et al., 2008 and Gilbert et al., 2014, Robinson et al., 2015), the cause and pattern of mortality events remains to be examined in tiger population across its known distribution range. Even in available studies, apart from anthropogenic causes of mortality, death due to natural causes and infectious disease are minimally documented (Gilbert et al., 2014). In this context, a study of such mortality events is of utmost importance, as they can aid in providing critical insight into array of factors responsible for mortality in tigers. Thus, the present study entitled “Patterns of mortality in free ranging tigers” was undertaken by Wildlife Institute of India as a part of the ongoing NTCA funded project titled “Strengthening Veterinary Interventions in Tiger Reserves”.

Objectives:

1. To determine the causes of mortality of free ranging tigers across the Indian landscape.
2. To assess the existing protocols being followed and identify critical shortcomings in mortality reporting process.

2 METHODS

METHODS

Review of mortality records/ Data sources

To ensure that the causative factors for each tiger mortality events are ascertained and taken to logical conclusion, the National Tiger Conservation Authority (NTCA) has issued a Standard Operating Procedure (SOP) that provides the basic, minimum steps that are required at the field level (tiger reserve or elsewhere) for dealing with incidents of tiger mortality. The SOP involves submission of a "FINAL REPORT", in prescribed format (including necropsy reports and associated laboratory reports) for each case of tiger mortality/ seizure to NTCA, which further acts as a repository and maintains a nationwide database of all such events. NTCA also hosts an online repository called as TIGERNET (www.tigernet.nic.in) in association with TRAFFIC-India, with an aim of online compilation of authentic records on mortality of tigers and other key wildlife species across India. The data for this study was obtained from above two information sources for the period of January 2011 to September, 2016. The details are provided below:

- NTCA repository: Individual necropsy reports and supporting documents such as pathology and forensic reports for documented tiger mortality events across the country between January, 2011 and September, 2016
- TIGERNET: Additional relevant information as available, for each reported tiger mortality event across the country between between January, 2011 and September, 2016.

Mortality trends across landscapes

The recent tiger conservation strategy emphasizes the need to expand conservation efforts to include more than one meta-population, leading to identification of ''Tiger Conservation Landscapes''. These include a number of protected areas interconnected by corridors that could potentially support viable populations (Sanderson et al., 2006). Available mortality reports were segregated initially according to 5 such tiger conservation landscapes in India, as identified in 2014 countrywide assessment of tiger status (Jhala et al., 2015). These included the Shivalik hills and Gangetic plains landscape, Central Indian & Eastern Ghats landscape, Western Ghats landscape, North East Hills and Brahmaputra Flood Plains landscape and Sundarbans landscape (Details in previous section). The year-wise information from the complete data set was used to assess the mortality trends across landscapes.

Gender and age class based trends

Under each landscape, mortality reports from the complete data set were further classificated based on gender (Male, female and unidentified) and age class (Cubs, <1years; young adults, 1– 3 years; Adults (3 - 10 years); old adults, > 10 years) to evaluate the existent threats and mortality pattern in each group.

Cause specific mortality

To understand the specific causes of mortality, available necropsy records and information from TIGERNET were assessed and based on confirmatory diagnosis (as mentioned in these reports), mortality events were segregated initially into 4 categories *viz., n*atural mortality, mortality due to diseases, human caused mortality, and inconclusive cause. The criteria to segregate the causes into above four categories were as follows:

Natural mortality: The cases classified into this category included mortalities due to following

- Intra-specific aggression: Mortalities caused by other tigers due to territorial aggression or infanticide by males.
- Inter-specific aggression: Mortalities caused by other species, either by prey during hunting sessions or by other sympatric carnivores.
- Cub mortality from starvation or separation from mother
- Senility: Mortalities caused by old age related factors, with no other detectable specific disease processes.

Mortality due to diseases: The cases classified here included mortality due to both specific infectious diseases and non-specific causes like emaciation.

Human caused mortality: The cases classified in this category included resultant mortalities from

- Accidents: Mortalities which were caused by vehicular or train accidents; fire or drowning.
- Poaching: Mortalities which were intentionally caused by poisoning; electrocution; fire arms or by using snares/ jaw traps.
- Legal elimination: Tigers killed as part of conflict mitigation strategy, due to the threat posed by them to human life.

Inconclusive: The cases classified in this category included mortality without any confirmatory diagnosis (excluding senile/emaciated animals) or supporting documents.

Location-wise reporting of tiger mortality

Tiger populations today survives in a mosaic of protected areas surrounded by human dominated landscapes having limited protection status. These areas besides maintaining connectivity between populations (Joshi et al. 2013) support considerable population of tigers and aid in dispersal by providing corridors that helps in genetic exchange (Chapron et al., 2008; Yumnam et al., 2014). Despite the potential conservation significance of the areas other than PA's, scarcity of information limits an understanding on their role in the overall conservation of tigers. These areas pose a potential threat to the species as number of instances of poaching, poisoning, accidents and retaliatory killings have been reported. Thus it calls for studying mortality patterns in areas outside the PA and further comparing these events with those inside the PA system. Accordingly, the locations of mortality events were classified as those occurring in the PA Network and those outside from the complete dataset.

Effectiveness of reporting process

The 'Standard operating procedure for reporting tiger mortality' is the first attempt to establish a uniform database for all tiger mortality events that occur in India. Accordingly, the National Tiger Conservation Authority (NTCA) has issued detailed guidelines on the procedures to be adopted while carrying out necropsies as well as documenting and reporting information to enable an effective decision support system. To assess the effectiveness of reporting process being carried out by the various tiger reserves, following two aspects were considered

- Time gap between mortality and carcass detection (0 – 1 day, 2 – 5 days, 6 to 10 days, 10 days and above and unknown)
- Information on condition of the carcass (Fresh, active decomposition, putrefied and incomplete carcass)

Documenting disease threats

Efforts were made to document infectious and non-infectious diseases reported in tigers to highlight the possible disease threats in tigers across their global range through extensive review of available literature. Web of Knowledge and Google Scholar were used to search all major wildlife and zoo animal health, veterinary and ecological journals for disease reports in tigers. Published books on wildlife diseases and references of published articles were also reviewed to find additional literature, including technical reports and unpublished dissertations.

Assessment of existing necropsy protocols

During each tiger mortality event, Standard Operating Procedure for dealing with tiger death, as advised by NTCA needs to be followed. NTCA has also circulated an advisory with a prescribed format for the record of post-mortem examination during such event (NTCA's Advisory. No.1-9 / 93-PT, dated July 15th, 2010). Deviation from this often results in varied quantity and quality of the data available; hindering attempts to arrive at a logical conclusion. To address the issue, existing necropsy protocols being followed in tiger reserves and other PA's were assessed based on available PM reports for their compliance with NTCA's Standard operating procedures (SOP's). Certain critical shortcomings in reporting process were also identified and suitable recommendations were made accordingly to rectify them.

3 RESULTS

RESULTS

Based on the available data of mortality events from NTCA repository and TIGERNET, a total of 407 tiger mortalities were reported across different landscape between January, 2011 and September, 2016. Scrutiny of records revealed following available information

1. Individual necropsy reports available for 189 cases (46.4 % of total reported cases)
2. Additional information to address specific cause of mortality was available for 11 cases from TIGERNET.
3. Information to address the landscape level and age and sex specific mortality was available for 212 cases from TIGERNET.

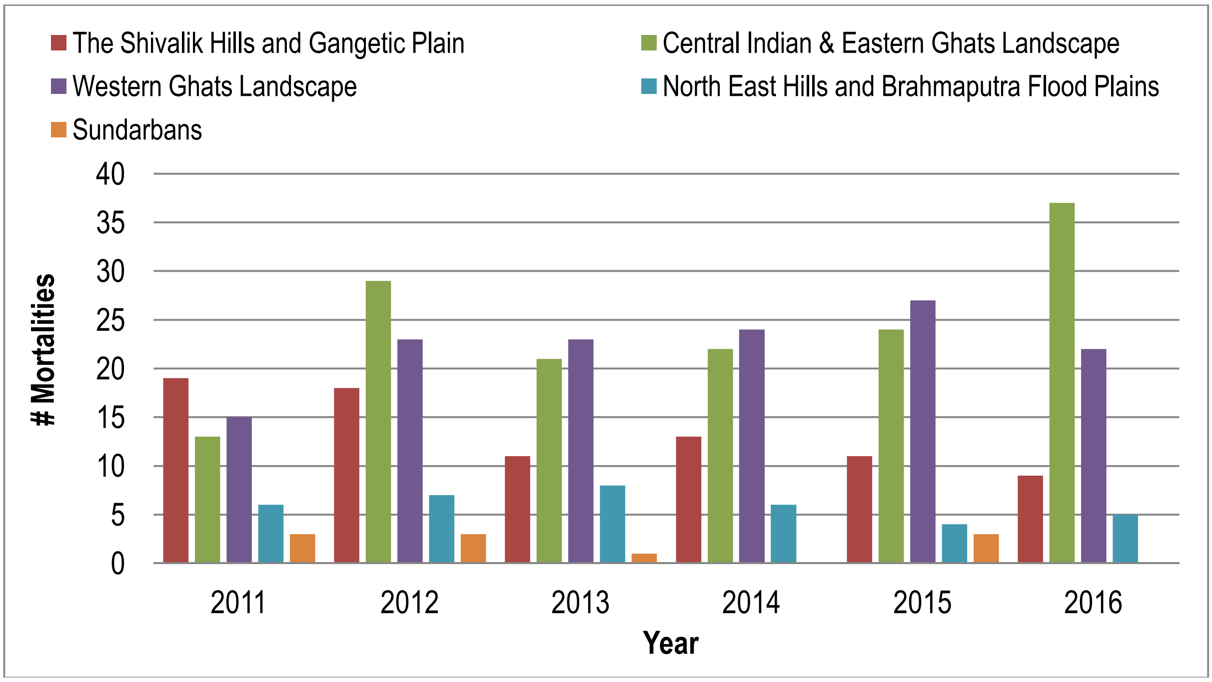
Though the data from TIGERNET reported additional 68 cases of tiger part seizures, these were excluded from analysis as these could not be traced back to individual landscapes and did not reveal any information to enable the establishment of cause or pattern of these mortalities.

Mortality patterns

Mortality trends across landscapes

Year-wise distribution of reported tiger mortalities across 5 landscapes are presented in Figure 3.1 and shows a close association with the number of tigers reported from respective landscapes. Maximum cases were reported from the Central Indian & Eastern Ghats followed by Western Ghats, Shivalik hills & Gangetic plains, Northeast hills & Brahmaputra flood plains and lastly Sundarbans.

Figure 3.1: Year-wise distribution of reported tiger mortalities across 5 landscapes.



Gender and age class based trends:

The mortality trends based on the gender and age class is provided as Table 5. Analysis for the gender based trends revealed 36.9% and 32.9% events to be that of males and females respectively, however, gender identification could not be established for 30.2% of individuals.

Dataset of all the 407 individual cases could be used for classifying mortalities based on age classes. The study revealed maximum mortality (29.5%) among the adult age class (3-10 years) followed by 12.50% cub mortalities (less than 1 year), 12.3% mortalities among young adults (1-3 years), 11/1% mortalities among older age group (>10years). The age estimates for 34.6% events could not be established probably due to delayed carcass detection and advanced stages of putrefaction of carcasses.

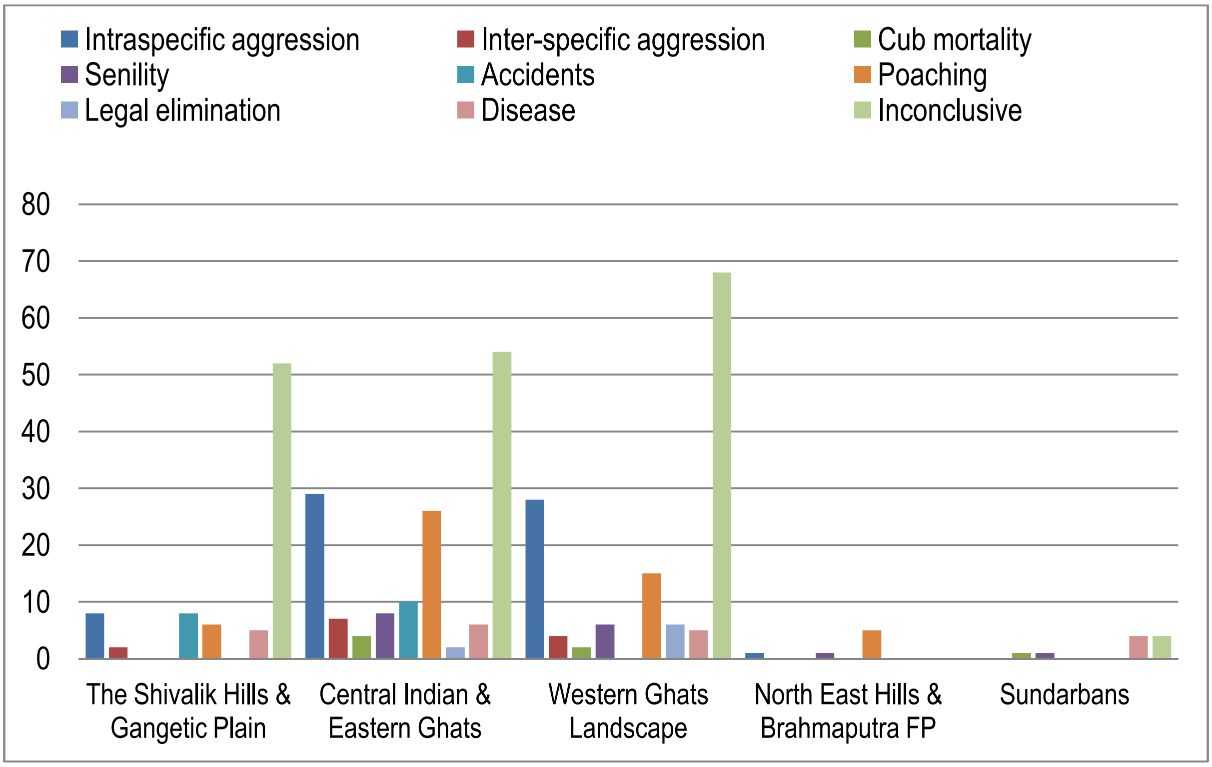
Table 3.1: Landscape wise distribution of tiger mortalities, based on age classes and gender from 2011 – 2016

Landscape	Year	Gender			Age Class				
		Male	**Female**	**Unidentified**	**< 1**	**1 to 3**	**3 to 10**	**> 10**	**Unknown**
The Shivalik Hills and Gangetic Plain	2011	7	11	1	2	2	6	0	9
	2012	8	2	8	5	0	5	1	7
	2013	2	6	3	1	3	1	0	6
	2014	2	6	5	1	1	3	2	6
	2015	5	6	0	1	0	8	2	0
	2016	4	2	3	0	1	2	3	3
Central Indian & Eastern Ghat Landscape	2011	3	9	1	0	1	4	3	5
	2012	12	9	8	3	4	9	2	11
	2013	2	9	10	4	2	3	3	9
	2014	6	10	6	3	4	5	0	10
	2015	10	4	10	8	6	4	1	5
	2016	12	18	7	7	5	10	9	6
Western Ghats Landscape	2011	8	2	5	0	2	5	2	0
	2012	12	4	7	2	5	11	2	2
	2013	8	2	13	0	3	8	3	0
	2014	10	3	11	2	3	5	3	2
	2015	14	10	3	7	2	14	3	7
	2016	8	8	6	2	0	8	3	2
North East Hills and Brahmaputra Flood Plains	2011	1	3	2	0	1	0	0	5
	2012	2	2	3	0	2	0	0	5
	2013	4	3	1	2	0	1	1	4
	2014	1	1	4	0	0	2	0	4
	2015	3	0	1	0	1	2	0	1
	2016	0	3	2	0	1	1	0	3
Sundarbans Landscape	2011	2	0	1	0	0	2	0	1
	2012	1	0	2	1	0	0	1	1
	2013	1	0	0	0	0	0	1	0
	2014	0	0	0	0	0	0	0	0
	2015	2	1	0	0	1	1	0	1
	2016	0	0	0	0	0	0	0	0
Total		150	134	123	51	50	120	45	141

Cause specific mortality:

Based on the available information, specific causes of mortality could be ascertained in 200 instances, of which 102, 20 and 78 were attributed as natural mortality, mortality due to diseases and human caused mortality respectively. The remaining 207 cases were inconclusive. Specific causes of mortality in each landscape for the study period are represented in figure 3.2.

Figure 3.2: Cause specific patterns of mortalities in each landscape (January 2011 to September, 2016).



Natural causes:

Intra-specific aggression: Intra-specific aggression between individuals caused 67 mortalities (65.7 %), accounting for highest number of deaths among natural causes. These also included the infanticide due to intruding tigers.

Inter-specific aggression: Inter-specific aggression involving other species caused 12 mortalities (11.8 %), with Gaur (*Bos gaurus gaurus*) being the main species and dholes, wild boars, porcupine and domestic livestock responsible for causing injuries resulting in mortality in tigers.

Cub mortality: Seven cases (6.9%) of cub mortality were reported among all the necropsy confirmed mortality events and were attributed to starvation following separation from mother. Though there were cases of infanticide by males, those have been included in Intra-specific aggression.

Senility: Sixteen cases (15.7%) among natural mortalities were attributed to old age related factors, with no other detectable specific disease processes.

Unnatural causes:

Poaching: Poaching accounted for 52 (66.7%) of mortalities under unnatural causes. Among the poaching cases, 30 (57.7%) were attributed to poisoning, 12 (23.1%) to electrocution, six (11.5%) due to injuries from snaring or trapping, and in two (3.8%) instances each, the animals were directly beaten to death and shot dead following confrontation.

Accidents: Accidents accounted for a total of 18 (23.1%) mortality events of which eight were from vehicular collision, four due to train collision, four due to unintentional fire, one each from drowning in open well and injuries sustained due to falling of tree trunk.

Legal elimination: Among reported cases, eight (10.3%) tigers were shot dead as part conflict mitigation strategy over the study period.

Diseases:

Twenty cases (10 % of total cases) were observed to be due to diseases. Four mortality events were confirmed to be due to Canine Distemper Virus with two cases from Panna Tiger reserve (M. P), one each from Pilibhit Tiger Reserve (U.P) and Ramnagar Forest Division (UK). Additionally, seven cases of pneumonia were recorded besides one case of snake bite, one case of tick bite paralysis, three cases owing to severe gastro-intestinal parasitosis and four cases exhibiting generalized debility and emaciation, without any concurrent infectious disease.

Additionally, the post mortem records also revealed variety of gastro-intestinal parasites in tiger carcasses and included *Toxocara cati* (Kalagarh Tiger Reserve), *Taenia hydatigena, Ancylostoma sp., Toxascaris leonina, Gnathostoma spinigerum, Isospora felis, Sarcocystis spp.* (Panna Tiger Reserve), *Gnathostoma spp. (*Bhimghad Wildlife Sanctuary & Bandipur Tiger Reserve), *Galoncus spp. and Paragonimus spp. (*Kuthirakode Reserve Forest) and *Galoncus spp. (*Waynad Wildlife Sanctuary).

Collectively, among all specific causes, intraspecific aggression (29.0%) and poaching (28.3 %) were found to be two main drivers for tiger mortality in the country.

Location of mortality event

Of the total 407 mortalities considered for analysis, 289 (71.0%) cases occurred inside the protected areas (PA) and 118 (29.0%) cases occurred outside the PA. The detailed cause specific mortalities observed outside and inside PA's is provided in figure 3.3 and 3.4.

Figure 3.3: Mortalities observed outside PA's (January 2011 to September, 2016).

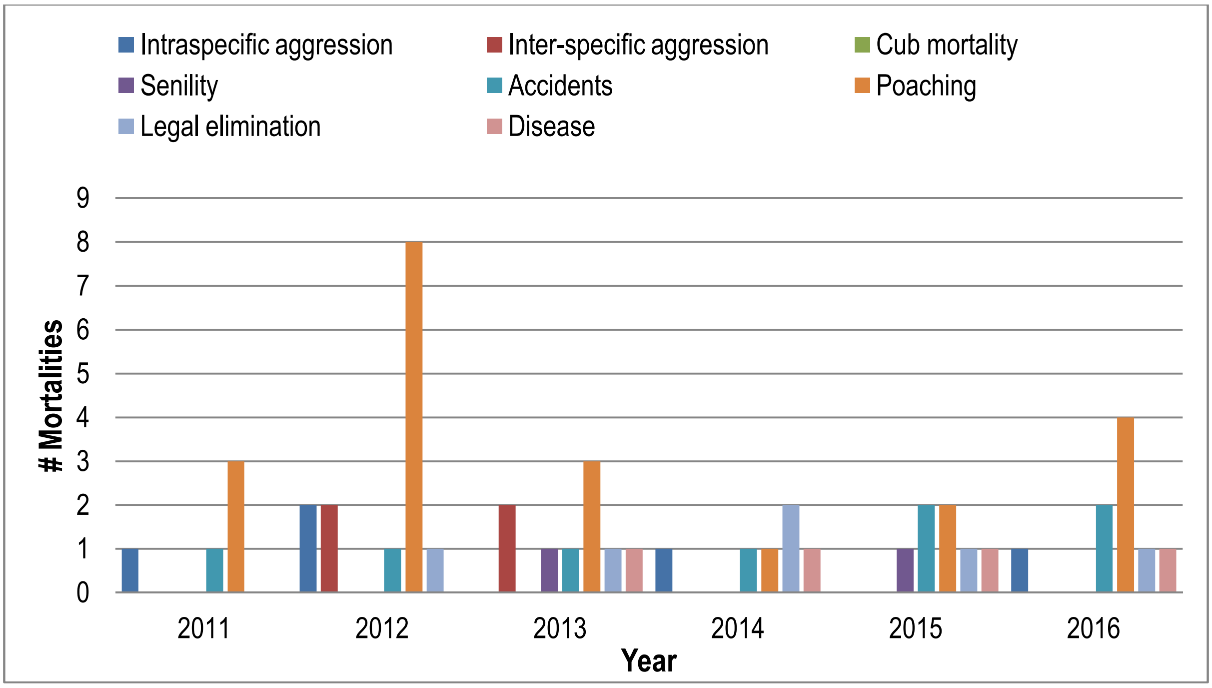
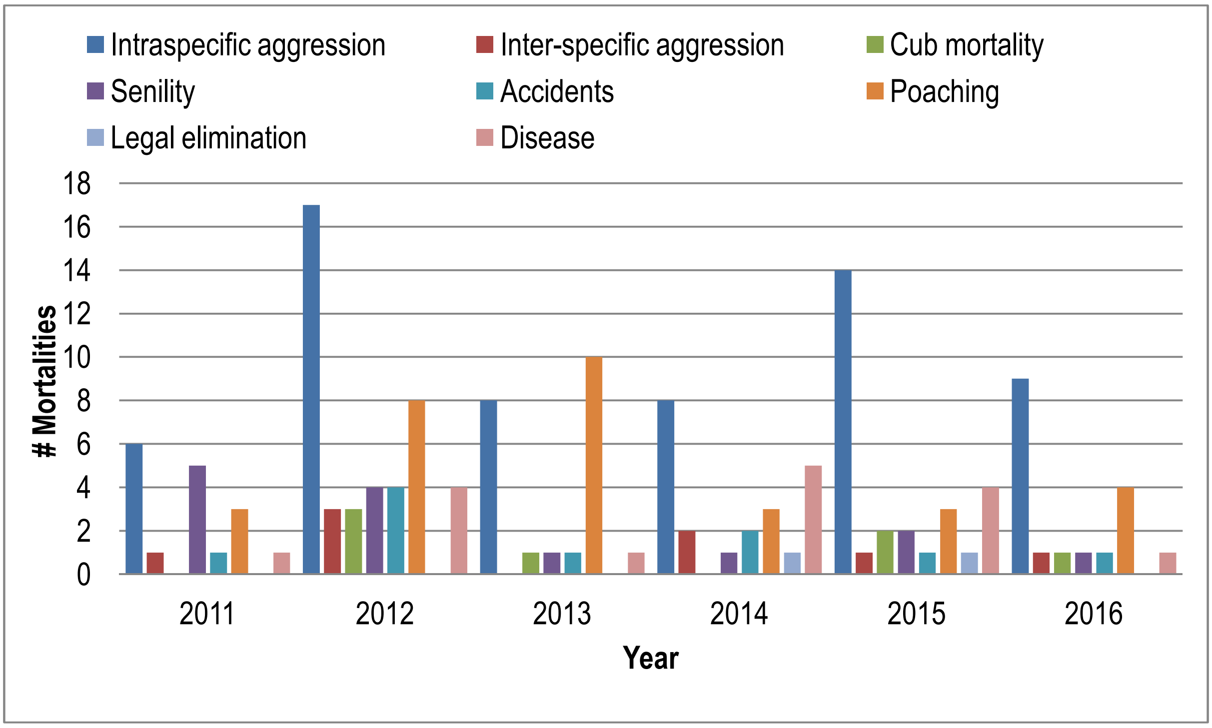


Figure 3.4: Mortalities observed inside PA's (January 2011 to September, 2016).



Effectiveness of Mortality Detection Process

Among 407 mortalities, 49 (12.0%) carcasses were located within a day of mortality, 57 (14.0%) within 2 – 5 days of mortality, 20 (4.9%) and 15 (3.7%) within 6 – 10 and > 10 days of mortality respectively. Time of death in 266 cases (65.4 %) could not be ascertained and the details are provided in Table 3.2.

Table 3.2: Effectiveness of Reporting Process

Landscape	Carcass detection time (days)					Condition of the carcass			
	0-1	2-5	6 –10	>10	Unknown	Fresh	Active decomposition	Putrefied	Incomplete
The Shivalik Hills and Gangetic Plain	8	7	0	1	64	5	3	5	2
Central Indian & Eastern Ghats Landscape	21	24	8	2	91	18	5	24	21
Western Ghats Landscape	19	22	9	11	74	17	12	30	10
North East Hills and Brahmaputra Flood Plains	0	4	3	0	29	0	1	7	0
Sundarbans Landscape	1	0	0	1	8	1	1	2	1
Total	**49**	**57**	**20**	**15**	**266**	**41**	**22**	**68**	**34**

Similarly, the condition of carcass prior to necropsy also formed basis for addressing the appropriateness for carrying out the procedures to meaningful conclusion. Fourty one carcasses were in early stages with minimal putrefactive changes; 22 in early stages of decomposition with existing rigor–mortis, while 68 carcasses had advanced stages of putrefaction. Further, 34 carcasses were defined as incomplete, owing to absence of parts due to poaching and scavenging.

Though information could be retrieved from most of the carcasses showing early stages of decomposition (fresh and active decomposition) from which conclusions regarding the cause of death could be drawn; only seven of the 68 carcasses having advanced putrefactive changes could be used to arrive at conclusion through laboratory support.

Documenting disease threats

The probable threats arising from diseases among tigers were reviewed through available published literature. Variety of pathogens including infectious and parasitic diseases has been documented to cause disease entity among both free ranging and captive populations. Table 3.3 includes a listing of infectious diseases reported from tigers.

Table 3.3: Infectious disease events recorded in tigers (*Panthera tigris*)

Pathogen	Diseases documented
Bacterial	*Colibacillosis, Hemorrhagic septicemia/ bronchopneumonia, Leptospirosis, Shigellosis, Salmonellosis, and Tuberculosis.*
Rickettsial	*Anaplasmosis, and Ehrlichiosis*
Viral	*Avian Influenza, Canine Distemper, Feline Calicivirus, Feline Coronavirus, Feline Immunodeficiency Virus, Feline Panleukopenia, and Rabies*
Prion	*Feline Spongiform Encephalopathy*
Fungal	*Coccidioidomycosis and Microsporum canis*
Protozoan	*Babesiosis, Cytauxzoonosis, Eimeria (E. harmani& E. novowenyoni), Isosporafelis, Sarcocystis spp., Trypanosomiasis, and Toxoplasma gondii*
Cestodes / metacestodes	*Pseudophyllidea spp., Taenia spp., Taenia hydatigena and Taenia taeniformis*
Trematode	*Dicrocoeliidae spp., Hymenolepididae spp., Paragonimus spp., Paragonimus westermanni, Platynosomum fastosum*
Nematode	*Ancylostomatidae spp., Aelurostrongylus spp., Bronchostrongylus Subcrenatus, Capillaria spp., Capillaria aerophila, Dirofilaria immitis, Galonchus perniciosus, Gnathostoma spinigerum, Molineus spp., Mammomonogamus, Ollulanus tricuspis,, Physaloptera spp., Spirocerca lupi, Strongyloides spp., Toxocara spp, Toxocara cati, Toxascaris, Toxascaris leonine, and Trichuris spp.*

A detailed account on disease events recorded in tigers including the origin (captive or free ranging) and location is attached as Annexure 4.

Assessment of existing necropsy protocols

The existing necropsy protocols followed across the country varied considerably. The reports minimally complied with NTCA's prescribed format. Even though, most of the available individual reports (189 cases) had enough evidence to arrive at a conclusive diagnosis/ cause of mortality, some cases were considered inconclusive, owing to advanced putrefactive changes and non-availability of supporting documents. Further, though partial information on remaining 218 cases had been communicated to NTCA by respective State Forest Departments; necropsy reports and supportive documents were not complete at the time of data collection.

4 DISCUSSION

DISCUSSION:

It has been well documented that tigers are endangered throughout their range and the current population estimates suggest a decline of 50% in global population in the recent past (Goodrich et al., 2015). Globally, poaching, habitat loss and prey depletion have been identified as the principle causes for tiger decline (Dinerstein et al. 2007) and similar observations have also been made in Indian subcontinent (Madhusudan and Karanth, 2002; Madhusudan, 2004; Shankar et al., 1998; Shahabuddin et al., 2004). Since the Indian subcontinent is estimated to harbor about 60% of the global wild population in an estimated 8–25% of remaining global habitat (Mondol et al., 2009), their conservation is extremely important.

Recent past has witnessed a spurt in knowledge with systematic studies on various ecological and behavioral aspects that forms the key to tiger conservation. Intensive research efforts have been expended and still continue to be made to study the ecology and biology of the species (Panwar, 1979; Karanth, 1991; Ramakrishnan et al., 1999; Jhala et al., 2008; Sankar and Johnsingh, 2002; Jhala et al. 2011; Harihar and Pandav, 2012; Sankar et al., 2013; Jhala et al. 2015, Chundawat et. al. 2016). These studies have supported conservation initiatives by assessing the ecological and biological drivers responsible for the long-term survival of the species. Few studies have; however, quantified mortality events and the possible effects of mortality rates, for the species throughout its known distribution range (Chapron et al., 2008; Goodrich et al., 2008, Gilbert et al., 2014, Sharma et al., 2014; Robinson et al., 2015). Studying patterns of mortality in tigers can reveal potential risk factors that may be impacting these populations.

Information about the distribution, significance, and trends of mortality causes is valuable for developing effective management strategies, particularly in cases of small and isolated tiger populations that are prone to local extinction (McCallum, 2012). Available studies on mortality patterns in tigers are mainly from the Russian Far East, and have been carried out extensively using data from radio-collared Amur tigers (Goodrich et al., 2008 Robinson et al., 2015). Even though there was considerable data on mortality of non-collared animals, the data were not preferred in above studies as the samples were considered biased towards tigers killed in tiger–human conflicts and underreporting of poaching cases. Further, natural deaths of the non-collared animals could rarely be detected in the 3985-km^2 tiger habitat (Goodrich et al., 2008).

Mortality detection and reporting process has been fairly good in the Indian context owing to intensive foot patrolling regimens and anti-poaching strategies inside reserves. An initiative by National Tiger Conservation Authority to maintain a centralized countrywide database of tiger mortality across diverse landscape was also the driver for this reporting. This was further supported by several advisories issued by the NTCA to all the tiger reserves and PA's that facilitated better mortality detection and prompt reporting process. The mortality database maintained by NTCA formed the basis to understand reported patterns of mortality in markedly varying tiger landscapes.

The present study was undertaken to assess the current threats to tiger population through available mortality records.

Mortality trends across landscapes: In India, many of the protected areas are too small or isolated to support viable populations of large mammals over the long term, and isolated populations of large vertebrates in such refuges have a high probability of local extinction (Wikramanayake et al. 2004; Ranganathan et al., 2008; Jhala et al., 2015). Recent conservation strategies emphasize the need to expand conservation efforts by including meta-populations (Wikramanayake et al., 2004) leading to identification of 'Tiger Conservation Landscapes' (TCLs) (Sanderson et al., 2006).

The success of landscape conservation approach depends critically upon a detailed understanding of population dynamics, along with distribution and dispersal events (Joshi et al., 2013). The spatial distribution and dispersal events of tigers in the Indian subcontinent (Gour et al., 2013; Joshi et al., 2013; Jhala et al., 2011; Jhala et al., 2015) including population dynamics to certain extent (Karanth et al, 1991) has been reasonably well studied. However, studies on the rates and causes of mortality that play an important role in influencing population dynamics are limited.

The results of the present study showed a close association of reported tiger mortalities with the number of tigers reported from respective landscapes. Maximum cases were reported from Central Indian and Eastern Ghats (35.9%), which traverses across the political boundaries of Rajasthan, Odisha, Madhya Pradesh, Maharastra, Jharkhand, Chattisgarh, Andhra Pradesh and Telangana. Tigers occupy 41,974 km^2 of this landscape, with presence of 688 (SE range 596-780) individuals (Jhala et al., 2015).

In the recent past, the landscape has experienced challenges from development projects that include roads, railway, urban sprawl and mining, which are adversely affecting the tigers of this landscape in a plethora of pathways. Thus, appropriate mitigation measures have to be implemented, to ensure that development projects do not become barriers in conserving the species.

The Central Indian and Eastern Ghats landscape was followed by Western Ghats (32.9%), which traverses across the political boundaries of Goa, Karnataka, Kerala and Tamil Nadu. The landscape also hosts the world's largest tiger population (Nagarhole-Bandipur-Mudumalai-Wayanad-Satyamangalam-BRT complex). This was followed by Shivalik hills and Gangetic plains (19.9%), Northeast hills and Brahmaputra flood plains (8.8%) and lastly Sundarbans (2.5%). This knowledge on mortality if combined with survivorship data can provide a foundation for population models for assessing population persistence with observed mortality rates.

Even though the Northeast hills & Brahmaputra flood plains traverse across states of Assam, Arunachal Pradesh, Mizoram and northern part of West Bengal, the reported tiger mortalities were only from the state of Assam, suggesting under-reporting of cases probably due to inaccessible terrain and deficiency of trained staff. This partially holds true in respect of the Sunderban landscape also as the mangrove habitat provides a formidable challenge for conducting routine monitoring due to limited connectivity and difficulties in employing standard patrolling practices. Thus, there is a high probability of mortality events going unnoticed, leading to biased results.

Gender and age class based trends: Several studies have shown that in slow-growing populations like tigers, characterized by late maturation, small litter size, and long life spans; population growth is influenced more by adult survival than by reproduction (Heppell et al., 2000; Crone 2001; Oli and Dobson 2003). Tigers and most large carnivores alike have also evolved under conditions of high survival of breeding adults (Weaver et al., 1996); however, studies have shown that human caused mortalities can seriously impair this cohort (Goodrich et al., 2008).

Chapron and co-workers (2008) documented that small changes in adult female survival can have large effects on a population's probability of persistence. The analysis for the gender based trends from the available data revealed 36.9% of mortalities among males and 32.9% mortality among females. The data only provided some information on mortality patterns; however, definitive conclusions would require actual survivorship data.

The study revealed maximum mortality of 29.5% among the adult age class (3-10 years) followed by 12.5 % cub mortalities (less than 1 year), 12.3% mortalities among young adults (1-3 years), and 11.1% among older group (>10 years). As even small changes in adult survivorship may have serious consequences for their persistence, especially in isolated populations, the factors leading to such events need to be addressed.

Cause specific mortality: Habitat loss, poaching, and prey depletion have often been cited as the three primary threats for tiger conservation though there is a debate over the relative importance of each (Chapron et al., 2008). The present study documents cause-specific mortality patterns confirmed through necropsies across Indian landscapes. Among the causes, 51.0% were attributed to natural causes, followed by 39% to human induced causes and 10% resulting from diseases. The most significant findings of the study were the relative importance of intraspecific aggression (33.5%), in addition to poaching (26.0%) that formed the two main drivers for tiger mortality in the country.

Intraspecific aggression: Intraspecific aggression is a natural interaction in population ecology, whereby members of the same species compete for limited resources. Karanth and Stith (1999) suggested that generally about 10-25% tigers which are older than a year die annually as a combined result of aggression, hunting injuries or starvation. However, based on results of the present study, intraspecific aggression is likely the major cause of mortality and may have resulted from physical shrinkage and fragmentation of habitat. The results further support the conservation strategies focusing on landscape planning, which protect breeding populations as source pools and provide dispersal opportunities by linking habitat patches across the landscape mosaic thereby decreasing the competition for resources.

Poaching: The results of present study concur with other published studies for the species (Chapron et al., 2008; Goodrich et al., 2008 and Robinson et al., 2015) with poaching continuing to be the major cause for mortalities among tigers across Indian landscape. While poisoning was the most preferred *modus operandi* according to the observation of present study, snares, jaw traps, live electric wires and fire arms were also used in many cases to poach tigers.

A recent study by Sharma and co-workers (2014) showed that areas with greatest risk of tiger poaching and trafficking are situated in a narrow corridor running from South India, through Central India, all the way to specific border districts in the north. The results of present study correlate with above findings as 78.8% (41 out of 52 confirmed poaching cases) were reported from Central Indian, Eastern Ghats landscape and Western Ghats landscape collectively. Further, as observed in the same study, considerable cases (11.5%, 6 out of 52 confirmed poaching cases) were also observed from the Shivalik hills and Gangetic plain landscape, which comprises states bordering with Nepal, the main international hub for trafficking of tiger parts into China (Nowell, 2000; Verheij et al., 2010; Wright, 2010). However, it is worth noting that less number of tiger poaching in other landscapes does not necessarily indicate its absence. Conversely, an increase in the number of reports of tiger poaching in certain reserves cannot be necessarily interpreted as an increase in crime rate, as it could instead be a reflection of better enforcement.

Besides above, the study revealed existence of other significant causes of mortality among tigers and included mortality due to diseases (10.0%), accidents (9%), Senility (8%), inter-specific aggression (6%), legal elimination (4%) and cub mortality (3.5%).

Diseases: Twenty necropsy confirmed cases (15.9% of total cases) were observed to be disease related in the present study. Cases showing emaciation and debility, with no other detectable concurrent infectious disease processes accounted for 20% (four out of 20 cases) of mortalities. In majority of these cases, pathological changes indicated multiple organ failure and yielded mixed flora on bacterial cultures. Post-mortem autolysis and contamination of pathogenic bacteria by opportunistic species could not be ruled out.

The finding of the present study revealed involvement of respiratory system in seven out of 20 cases that were classified as mortalities due to diseases. The characteristic observation in all these cases was pneumonic changes including evidences of severe respiratory infections. Certain cases were also associated with nematode parasitism, leading to interstitial pneumonia and subsequent bacterial infiltration and death. Since gross observations in the field are inadequate to detect subtle signs of diseases, it necessitates proper biological sampling to ensure laboratory backup for each diagnosed event. In general, misdiagnosis has been observed as one of the main reasons in misinterpreting mortality causes in other wildlife studies.

Four of the mortalities during the study period were attributed to Canine Distemper; with two cases from Panna Tiger reserve (Madhya Pradesh), one each from Pilibhit Forest Division (Uttar Pradesh) and Ramnagar Forest Division (Uttarakhand). A study on mortalities in Amur tigers revealed about 8 to 13% of the mortalities due to canine distemper likely contracted from domestic dogs (Robinson et al., 2015). A sero-prevalence study carried out on tigers in Russia showed 15% of the tigers to be having antibodies against canine distemper virus with few exhibiting stuporous state with no apparent recognition or fear of humans (Quigley et al., 2010, Goodrich et al., 2008). The disease has been reported to alter behaviour of tigers possibly leading to human – tiger conflict and an additional negative influence on tiger population. These findings also highlight the need for detailed necropsies and laboratory confirmation to arrive at meaningful diagnosis; findings of which can be effectively used for further management.

Accidents: Accidents accounted for a total of 18 mortalities (9%) of which eight were from vehicular collision, four due to train collision, four due to unintentional fire, one each from drowning in open well and injuries sustained due to falling of tree trunk. India's phenomenal economic growth (~8%) over the last two decades was based on an expansion of linear infrastructure such as roads, railway, and communication networks for improved commerce (Gubbi et al., 2014). However, roads and railway lines, some of which pass through ecologically important sites and protected areas constitute a threat resulting not only in habitat fragmentation but also in direct mortalities of wildlife due to collisions with vehicles or trains. The results of present study thus emphasise the need of mitigation measures such as slowing traffic/train speed, providing wildlife crossing structures and increasing driver awareness and whenever viable, realignment of roads and railway lines passing through PAs.

Senility: The traditional belief is that, animals don't grow into old age and succumb much earlier to "unnatural causes". In contrast, aging has a major impact on mortality in the wild (Bonduriansky and Brassil, 2002). Sixteen cases (8%) of the reported mortalities in present study were attributed to senility and had no underlying disease conditions. All these cases exhibited signs of starvation and debility, which could be manifestation of reduced fitness, similar to the observations made in other wild animals (Promislow and Harvey 1990).

Inter-specific aggression: Studies of predator–prey interactions continue to be one of the most important aspects of ecological research, attributing to importance of predation in driving population, community, and evolutionary dynamics (Mukherjee and Heithaus 2013). There is limited information available on injuries caused by prey on predators. Available information of injuries to predators generally are limited to studies of hard parts (e.g. teeth, bones) and underestimate prey induced actual mortalities that result from injuries to soft tissues or other parts of the body (Mukherjee and Heithaus 2013). Weapons and defensive structures of prey include hooves, spines, horns, tusks, teeth and venom that may have fatal result.

Injuries during hunting sessions are frequent and have been well documented (Corbett, 1946, 1957). High rates of fractured canines were recorded for many species of carnivores, including 5.4% of lions (*Panthera leo*), 9.2% of tigers (*Panthera tigris*), 9.8% of leopards (*Panthera pardus*) (Van Valkenburgh, 2009). In the present study, inter-specific aggression involving other species caused 12 mortalities (6 %), with Gaur (*Bos gaurus gaurus*) being the main species and dholes (*Cuon alpinus*), wild boars (*Sus scrofa*), porcupine (*Hystrix indica*) and domestic livestock being others responsible for causing injuries resulting in tiger mortalities.

Legal elimination: Human tiger conflict has long been existent in the Indian subcontinent. In the year 1877 alone, 798 persons were killed by tigers throughout the erstwhile British India (McDougal, 1987). There are numerous accounts in literature describing stories of man-eaters in northern India, including one tigress which killed 434 people before it was shot dead (Corbett, 1946). However, by the 1880's man-eaters were considered rare, because of extensive hunting of conflict animals (Gouldsbury 1923). Even though the recent trends indicate an increased potential for conflict between humans and tigers owing to increased anthropogenic pressure, instances of individual tigers turning into man-eaters are comparatively rare, with some exceptions. A much more common cause for human killings in recent past is the result of a surprise encounter between tiger and human, whereby the tiger may attack in self-defense or a tigress may attack for the safety of her cubs (Dinerstein et al., 2006). During the study period of 2011 – 2015, eight (4%) tigers were shot dead as part of conflict mitigation strategy in India with majority of cases occurring outside PA.

Compliance to NTCA's guidelines for declaration of big cats as 'maneaters' (ANNEXURE II, SOP to deal with emergency arising due to straying of tigers in human dominated landscapes, dated 30th January, 2013) would help in avoiding persecution of tigers which are not actual "man-eaters" and were merely responsible for human casualty due to chance encounter.

Cub mortality: Mortality rates of nearly 40% have been reported during the first two months in tiger cubs (Christie and Walter 2000). In the present study, only seven cases (3.5%) of cub mortality were reported among all the necropsy confirmed mortality events. These might be attributed to limited detection and higher chances of their carcasses being scavenged upon. Due to paucity of data on cub mortality rates in India, these results can be a baseline indicator.

Location of mortality event: Protected areas are extremely important for the long term viability of a large carnivore like tiger (Gibson et al. 2011). Protected areas cover only 5% of the land area in India and in the case of large carnivores that range widely; human dominated landscapes surrounding PA's functions as habitat sinks (Athreya et al., 2013). These areas, even if sub-optimal can have major impacts on expanding the effective 'niche' available to a species (Pulliam, 1988).

Present study showed that of the total 407 mortalities considered for analysis, 29.0% cases occurred outside the PA. These results further highlight the necessity for developing appropriate strategies for monitoring and protection in areas outside PA network.

Effectiveness of mortality detection process: The results of the study revealed that the time of death could not be ascertained in 65.4% (266) of the cases. Even though, all PA's in the country have their respective law enforcement and monitoring systems in place, the regimen being followed are focused towards anti – poaching activities and patrolling limited to forest roads or trails. It calls for intensive patrolling and monitoring with adequate capacity enhancement and infrastructural support to address this critical aspect of mortality detection.

Information could be retrieved from carcasses showing early stages of decomposition (fresh and active decomposition) and conclusions regarding the cause of death could be drawn for 7/68 cases showing advanced putrefactive changes, through laboratory support. Thus, the necropsy examination needs to be conducted soon after the death to arrive at a conclusive diagnosis. The findings also highlight the need for proper field sampling and laboratory support to arrive at a logical conclusion.

Assessment of existing necropsy protocols: Present study revealed that the mortality data varied widely due to variety of formats being used to document the mortalities. In general, the compliance with NTCA's prescribed format was minimal resulting in extraction of information for analysis challenging. To overcome these shortfalls, a protocol has been designed (Annexure 1) to assist the field veterinarians and protected area managers in thorough necropsy examination in free ranging tigers as well as in proper sampling and laboratory confirmation to aid in conclusive diagnosis.

5

CONCLUSION & RECOMMENDATIONS

Conclusion

Tiger, the largest of all extant felids, is a wide-ranging species endemic to the forests and grasslands of south and south-east Asia, the Russian Far East and north-east China (Forrest et al., 2011) and are the flagship species of their habitats. In the recent past, the species has witnessed a drastic decrease in available habitats and severe declines in populations resulting in three subspecies becoming extinct and the remaining six severely threatened. Intensive efforts by range countries to ensure survival persistence of tigers include delineation and protection of tiger habitats, enforcement of anti-poaching measures and efforts by the scientific community to arrive at an understanding of the underlying ecological and behavioral factors.

The present study focused on studying mortality patterns of tigers in India and aims at addressing the lacuna in the information on the drivers of mortality that are crucial for their effective management.The database of tiger mortality events maintained by NTCA formed the basis for the study.

The study revealed adults animals (3 – 10 years) to be the most vulnerable age class followed by cubs (≤ 1 year), young adults (1 – 3 years) and older animals (≥ 10years). Among the natural causes of mortality; intra-specific aggression accounted for maximum cases. Of the human induced mortality (poaching, accident and legal elimination), the maximum number of deaths were due to poaching. The study also highlighted presence of disease to be one of the causes for mortality though confirmatory cases were minimal. Canine Distemper, an emerging threat to tigers was also reported from four Protected Areas. Additionally a review of available literature in both captive and free ranging tigers revealed the presence of a plethora of pathogens to cause diseases in tigers.

A major lacuna in dealing with mortality investigation was inadequate information to conclusively establish exact cause of mortality. In almost 50% of the cases, a logical conclusion could not be made to determine the cause of mortality. It may be attributed to delayed recovery of carcasses and advanced stage of decomposition, making it inappropriate for necropsy and limiting oppurtunities for biological sampling and subsequent laboratory examinations. Additionally, inadequate information in the mortality reports and deviation from uniform reporting process across the country posed a major hinderence to conclusively establish the patterns of mortality.

The report is an attempt to to address the drivers of mortalities in tigers across Indian landscapes and highlights the gap in capacities, knowledge and understanding of professionals in dealing with mortality investigations.

Recommendations

The outcomes of the study indicate that the long term survival of tigers across different landscapes would require appropriate management interventions. Following actions would further support conservation actions being implemented in the field:

- The long-term persistence of tigers can be ensured by adapting a landscape level conservation approach with large contiguous habitats and abundant prey base to address the spatial requirements of dispersing tigers as populations grow.
- Intensive patrolling, protection and monitoring of tigers to ensure safety of tigers and early detection of mortalities to facilitate timely actions.
- Capacity enhancement of wildlife health professionals and support field staff in the area of mortality investigation with emphasis for general field procedures. This can be achieved through establishment of wildlife health facility in tiger reserves and veterinary schools located in close proximity with appropriate infrastructure and trained staff.
- Creation of infrastructure at field level to cater to the situations arising subsequent to mortality events.
- Proper biological sampling, preservation and transport to pre-identified laboratory should be an integral component of any investigation to ensure confirmatory diagnosis.
- Laboratory findings play a crucial role in accurate identification of cause of mortality besides revealing crucial information on presence of infectious diseases in the habitat. It is prudent to ensure proper laboratory support for confirmatory diagnosis through networking with veterinary institutions and laboratories.
- Adherence of modified NTCA guidelines/SOP for reporting mortality events in tigers to arrive at logical conclusions and to ensure uniform reporting with adequate information.

The document and the annexures to the report may be referred to ensure thorough investigation of mortality events to arrive at conclusive diagnosis. This would help in better understanding of drivers of mortality and provide a support for further management interventions.

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ANNEXURES

Annexure 1

NECROPSY PROTOCOL (PANTHERA TIGRIS TIGRIS)

Necropsies are performed to get further insight into the cause of death and include a careful examination of the carcass both externally and internally. Necropsies generate a series of gross observations that help in establishing a diagnosis. Subsequent investigations, such as histopathology, microbiology or forensic analysis are then guided to rule out various potential causes until an etiology is established. Regardless of whether it is an anthropogenic cause or natural mortality event, by consistently conducting necropsies, trends in population health can also be monitored.

Except for tigers that are routinely monitored, carcasses are generally recovered in conditions that pose a challenge for conducting proper post-mortem (PM) examination. This is due to the fact that the environmental conditions (high ambient temperatures) result in rapid putrefaction and majority of the times the carcasses are partially/ completely scavenged before being detected. Laboratory examinations thus play key role for the eventual diagnosis in such cases. Laboratory results clearly depend on how well the necropsy is performed in field and how carefully samples are collected, labeled, stored and transported to the laboratory.

Protocol described here is designed to assist wildlife professionals in carrying out all procedures that lead to establishment of cause of death.

PRE-NECROPSY PROCEDURES

Prior to initiating any procedure, it is important to have proper planning and preparedness for conduct of PM procedures. It is imperative to have basic logistic support in terms of equipment and professionals/expertise to carry out such procedures.

Necropsy equipment:

Minimum recommended equipment to be carried in a field necropsy kit are as follows:

Sr. no	Equipment	Minimal quantity
	Documentation equipment	
1.	Hand held GPS	1
2.	Digital camera	1
3.	Measuring tape	1
4.	15 cm - Plastic ruler (to be used as scale while photo-documenting lesions)	2
5.	Vernier calipers	1
6.	Portable weighing balance (300 – 500 kg)	1
7.	Metal detector	1
8.	Necropsy data sheets	10
9.	Clip board	1
10.	Permanent Marker	5
11.	Pencils	5
12.	Necropsy procedure and protocols	

Sr. no	Equipment	Minimal quantity
	Necropsy equipment	
1.	Sharp high quality necropsy knife	6
2.	Curved knife for skinning	1
3.	Knife sharpening stone or steel	1
4.	scalpel handles (of different sizes)	2 each
5.	Box of scalpel blades (based on handle size)	2 box each
6.	Small plain forceps	3
7.	Rat-tooth forceps	3
8.	Small dissecting scissors	2
9.	Large dissecting scissors	2
10.	Artery forceps	3
11.	Hack saw or bone saw	1
12.	Chisel and hammer	1 each
13.	Alcohol lamp or gas burner (to sterilize equipments on site)	1
	Sample collection	
1.	Disposable syringes (5 ml & 10 ml)	1 box each
2.	20G needles	1 box
3.	Ziplock bags	100 nos
4.	Large white plastic cutting boards (for cutting and photographing tissues)	2
5.	Vacutainer (EDTA Coated)	1 box
6.	Vacutainer (Plain/ clot activator coated)	1 box
7.	Cryo vials	100 nos
8.	Sterile swabs	100 nos
9.	Glass slide	1 box
10.	Slide container	2
11.	Plastic screw cap/ tight fitting wide mouth containers (for tissue samples)	50 nos
12.	Aluminium foil	2 rolls
13.	Labels/ labeling tape	2 sheets
	Preservatives	
1.	10% buffered formalin	
2.	Absolute alcohol	
3.	70% ethyl alcohol + 2% glycerine	
4.	Viral transfer media and RNA Later	
5.	Silica crystals	
6.	Saturated salt solution	
7.	Insulated cooler box with ice blocks	

Personal safety: Personal safety should be exercised while carrying out a Post mortem examination. Personal protective equipment (PPE) should include:

1. Overalls with a washable rubber apron
2. Rubber boots
3. Face mask and goggles to cover eyes, and
4. Double gloves (rubber or plastic gloves)
5. Disinfectants (70% ethanol, quaternary ammonium compound / biguanide)

Important considerations during necropsy examination (Sinha, 2010)

- Post mortem procedure is a specialist job and should be left to such person(s) who are suitably qualified for the same and have some previous experience and expertise of working with wildlife.
- Every detail of the procedure must be dutifully recorded. It is appropriate not to trust these to memory, to be committed to writing at some later stage. Recording the observation on a voice recorder or a note pad will be of great help.

NECROPSY PROCEDURES

Brief history: Accounts of health status of the animal including illnesses, recent treatments, laboratory findings, wounds, etc. should be noted in due consultation with protected area authorities. The area around the carcass should be thoroughly examined for evidences such as but not limited to presence of other tiger, signs of trauma, poisoning or anthropogenic activity, etc., to assist in establishing probable cause of death.

Assessing body condition: (a) Good and (b) Emasciated

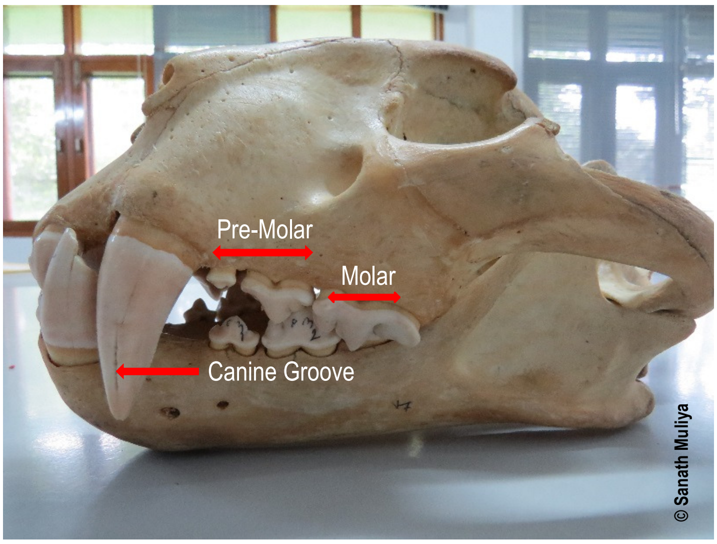
Necropsy site: Efforts should be made to transport the entire carcass to the areas designated in each tiger reserve or to nearby veterinary institution for conduct of necropsy. In case this is not possible (due to remoteness of area), efforts should be made to ensure that the team carrying out the necropsy reaches the site at the earliest and conducts all procedures with utmost caution including proper biological sampling and carcass disposal.

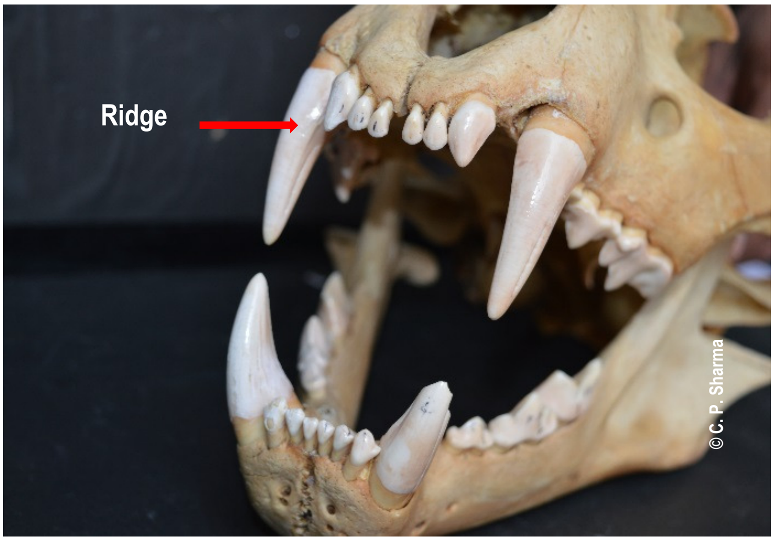
A committee consisting of veterinarian of the reserve, a veterinarian from animal husbandry department and a trained pathologist from a recognized veterinary college should be constituted to carry out the procedure. Additionally, the team should consist of one or two trained veterinary assistants to support proper conduct of procedures.

Collection of preliminary information: Since necropsy gives a unique opportunity to gather ecological and health data, it is worthwhile to collect all possible information. The information collected should include GPS co-ordinates and related data; time and date of necropsy examination; estimated time and date of occurrence of event; environmental conditions in the area; brief description of habitat and information for animal identification. The information for animal identification should include: age class (Juvenile, ≤ 1 Year; Sub adult 1 – 3 years; Adult 3 – 10 years or Geriatric ≥ 10 years), sex (male, female or unidentified), UTID: National Unique Tiger IDs assigned by NTCA and the Local ID (if any).

Ageing tigers: Apart from classifying animals into juvenile / cub group (based on obvious body size); the dentition and wear of teeth can be an indicator for classification into other age groups (Goodrich et al. 2001). Since it is practically impossible to determine the exact age of tigers unless they are being monitored from birth, the wear and tear in the dentition is a good indicator to arrive at an estimated age.

Tigers, similar to other felids; have fewer teeth (30) compared to canids and ursids (42) with bigger canines and shorter jaws (Kitchener et al, 2010). Teeth of tigers are exceptionally stout, with long and slightly curved canines (Mazák. 1981). The number and diversity of cheek teeth is reduced by loss of post-carnassial molars and the most anterior premolars, leaving a dentition that is highly specialized for carnivory (Kitchener et al, 2010). **The basic dental formula of felids is (I 3/3; C 1/1: PM 3/2; M 1/1) X 2 = 30 (**Mazák. 1981).





The teeth are subjected to unpredictably high load from struggling prey, which over time leads to wear and tear (Van Valkenburgh, 1988). As the age advances, tooth wear is manifested by change in color from whitish to pale yellow and later darker yellow. Gum line shows recession with considerable insult to teeth that includes either missing or at times broken teeth.

Based on the limited information from available records and observations during field operations, an attempt has been made to classify animals into different age classes based on dentition; however, it needs further corroboration by scientific documentation.

The subsequent section provides information on aging of free ranging tigers based on characteristics of their teeth and includes details of tooth eruption, time of replacement of deciduous teeth, degree of wear, appearance and fading / rounding of inner canine ridge, degree of staining and gum recession. Though these parameters may vary significantly among individuals of the same age and sex, these can be used to broadly group animals into the age classes of cub (0-1 years), sub-adult (1-3 years), adult (3-7 years), adults (7-10year) and old animals (≥10years). The supporting photographs with each age class are of free ranging tigers that were collected during necropsy examination and as part of the field capture operation. The different age classes based on dentition are as follows:

Young sub adult tiger having both deciduous as well as permanent canines on the upper jaw

1. Cubs (≤ 1 year): Tiger cubs are born toothless and their whitish deciduous (temporary) teeth come within a week or two after birth. At about six to twelve months of age, these deciduous teeth fall out and are replaced by stronger permanent teeth.

Whitish deciduous canine and incisors of 4 months, 6 months and 11 month (± 1 month) cub respectively

2. Sub adults (1 – 3 years): The permanent teeth are fully erupted, sharp, intact and mostly white. Prominent ridge can be appreciated on fully erupted canine as early as 18 months.

(1 &2) Sharp canines of a 27-month and 30-month old tiger (± 1 month) showing prominent ridge (3) Lower canine of same animal as 1 with prominent groove characteristic of felids.

4. **Adults (3 – 7 years):** Dental wear becomes obvious with slight staining of teeth. The ridges on the canines are prominent in this age class initially and gradually show wearing off (rounding) in animals above 5 years. The groove is quite obvious. Initiation of gum line recession starts in the age class.

(1) Sharp stained canines of a 3.5-year-old tiger (± 2 months) (2) A 5-year old tigress showing variable degree of staining and recession of gum line.

4. Adults (7 – 10 years): There is obvious wear on canines, incisors, and pre-molars. Stained yellowish canines with worn off ridge and varying degree of gum recession can be appreciated in this age class. Canine groove deepens. Marked staining and variable state of chipping on distal side of canine may be seen as age advances. Longitudinal ridge may completely fade or is totally rounded. Marked gum recession, broken canines/ missing incisors are not uncommon

(1) Seven-year-old tiger with marked staining and gum recession. (2) Broken and missing tooth may not be uncommon as evidenced in 7 year old tiger (3)The occlusal/ incisal surface of incisors shows varying degree of wear including flattening as age advances (indicative that the animal is in mid life)

5. Old Animals (≥ 10 years): Canines are often partially or completely broken showing extensive wear and damage. Incisors may be missing or completely worn off and marked recession of gum line may be noticed.

Marked wear and insult to canine and incisors can be appreciated in the age class. Missing teeth are not uncommon.

Additionally, gum-line recession can be used more reliably in wildlife studies as an indicator of age for tigers. Gum-line recession is defined as the distance (mm) from the cementum - enamel junction to the gingiva (i.e., gum-line) on the left and right upper canines (Spinage, 1973). It is the exposure in the root of the teeth caused by a loss of gum tissue and/or retraction of the gingival margin from the crown of the teeth as age advances (Fàbregas and Garcés-Narro, 2014).

Age (in months) = 20.47 + 12.60 X Mean gum – line recession

Based on results, animal can be then grouped into one of the four age classes, *viz.,* Juvenile, ≤ 1 Year; Sub adult 1 – 3 years; Adult 3 – 10 years or Geriatric ≥ 10 years.

Determination of gender: If the carcass is not detected early enough, putrification and scavenging might lead to difficulty in identification of the sex of tiger. Pugmark analysis suggesting the concept of square and rectangular frame in male and female respectively has served as a cost-effective, reliable, and accurate tool for monitoring sex ratios of free ranging tigers (Sharma et al., 2003). Thus, if a clear pugmark is available on a flat surface near the carcass, it could be used to identify the sex of dead tiger. A more accurate method; however, would be forensics based examinations, wherein PCR amplification using a set of primers helps determine the sex of the tiger (De candia et al., 2016).

Thus, in cases where sex of the tiger is uncertain, tissue samples should be collected and stored in 90% ethanol. The tissue should be completely immersed in ethanol and transported to designated forensic laboratories within 5-7 days.

Recording vital morphometric measurements: Vital morphometric measurements such as body size and size of body structures are intimately related to life history and ecology of species (Temerin et al. 1984). Analysis of accumulated morphological data over period can aid in various ecological studies, including age estimation, gender identification and identifying dietary strategies (Athereya and Belsare 2008; Heymann et al. 2012). Since immobilizing tigers solely for the purpose for obtaining such data is not feasible, opportunities such as necropsy examination should be full utilized to collect such data. The minimum measurements to be documented in each carcass should include canine lengths (upper and lower), inter-canine width, gumline recession, length and breadth of forefoot paw (right and left), a body weight, height and length. Since body measurements are accurate only if taken from fresh carcass, bloated and decomposed carcass should always be excluded.

External Examinations: Actual necropsy procedure begins with thorough external examination, that can support and lead to some key findings. These are briefly discussed below.

1. Necropsy interval: Estimation of time of death (necropsy interval (NI)) is crucial as its influence the appropriateness of the conduct of necropsy procedures. As many factors operate soon after death, post mortality changes vary to a great extent in each individual. Rather than using one particular parameter, combination of parameters may be considered to allow estimation of necropsy interval with reasonable accuracy (Oates et al., 1984).

Evidence for estimating NI may come from "Carcassial evidence" i.e. evidences that are present in the body such as rigor mortis, state of decomposition, presence of insects (forensic entomology) etc. Additional information from environmental and associated evidences (that are present in the vicinity of the body) and anamnestic evidence (in monitored animals, evidences based on the animal's movements, last known sighting and location etc.) may help in assessing the NI.

2. Rigor mortis: Rigor mortis is one of the recognizable signs of post mortem changes, its onset and duration is governed by temperature (lower ambient temperatures accelerates the onset of rigor and prolong its duration, whereas the opposite is found in warmer temperatures), metabolic state of the body (vigorous activity immediately prior to death) and prior disease if any. Even though time of appearance and disappearance of rigor mortis cannot be generalized, it can be still used to establish an estimate range. Typically, the stages observed over time lapse based on Oates and co-workers (1984) are as follows:

	Stage	Time lapse since mortality event
1.	Carcass is fresh and rigor mortis is absent (flaccid state)	> 1 hrs
2.	Rigor setting in	1 to 6 hrs
3.	Rigor complete	6 - 24 hrs
4.	Rigor passing off	12 - 36 hrs

3. Changes in the eye: Following death the eye luminosity, color of pupil, and its constriction can form basis for estimating necropsy interval (NI). At death, the cornea and eye fluids are transparent and the surface of the eye is tight and smooth. The transparency and luminosity decrease as the intraocular fluids become cloudy. A basis to estimate NI in White tailed deer using the technique described by Gill and O'Meara (1965) may form basis to estimate the NI with suitable modifications taking due considerations of the environmental factors, anatomical peculiarities and metabolic rate of the animal.

Hours	Changes in eyes
0.5	Eye lens and fluids fully transparent Light reflected from within the eye appears brilliant luminous green Pupil size however depends upon the prevailing light intensity at time of death. Pupil fully dilated shortly after death as the muscles are relaxed .

Hours	Changes in eyes
0.5 - 6	Lens and fluids remain transparent Luminosity and color may decrease slightly Pupil fully dilated and is almost round (as rigor progresses the pupil gradually flattens).
6 - 10	Colour changes toward gray Luminosity fades Pupil width may decrease to about one half original diameters.
12 -18	Colour fades to dull gray Luminosity fades away Pupil may narrow to one-third or less of original diameter.
30 and above	Color and pupil diameter remain the same. Hazy blue color appears over brown colored iris after about 48 hours. Normally on the third to sixth day after death, the eyeball partially collapsed

Additionally, changes in the skin (color and elasticity), mucus membranes (color), level of putrefaction, bloating and discharges from natural orifices can form basis in establishing NI.

4. State of decomposition: Decomposition occurs due to enzyme breakdown of tissues (autolysis), and bacterial activity (putrefaction). The process is known to be affected by ambient temperature, weather, size of the body, body composition, age and health of the animal (Brown, 2009). In general, carcasses can be assigned to following stages, based on state of decomposition.

Stage of carcass	Changes observed
Fresh	• Characterized as the beginning of decomposition immediately following death. • There are relatively few changes occurring during the fresh stage and the odor associated with the remains will still be the natural smell of the body (Parsons, 2009). • The fresh stage continues until the first signs of bloating begin, which is highly variable depending on the external environmental temperatures and conditions.
Early decomposition	• Early decomposition is marked by beginning of bloating in abdomen region and the skin begins to take on a green discoloration. • During the bloating period, the body begins to purge decompositional fluids and blood is released from the natural orifices (Terneny, 1997). • Bloating can occur rapidly in warm temperatures and last 2-5 days, however, it is extremely temperature dependent (Parsons, 2009).
Advanced decomposition	• Advanced decomposition starts with end of bloating phase; the tissues will sag and the abdominal cavity will have a sunken appearance. • Skin will take on a “wet” appearance where the liquefaction and disintegration of tissue begins (Payne, 1965). • The abdominal cavity will remain moist while other areas of the body such as the extremities will exhibit mummification or partial skeletonization depending upon external environmental conditions (Megyesi, 2005). • The odor of decay during this phase is strong and putrid and can be detected over long distances (Parsons, 2009).
Skeletonization	• Early phases of this stage are identified when the majority of soft tissue has decomposed or when mummified tissue begins to break down to reveal bone (Megyesi, 2005). • Odor is minimal and takes on a musty or moldy smell. • It can take place as quickly as two weeks in hot and humid environments but takes much longer to reach in areas characterized by cold and dry climates (Parsons, 2009).

Additional information: The condition of the heart may also be used as an indicator of the time of death and degree of postmortem change. The presence of unclotted blood in the left ventricle usually means that death was recent and rigor mortis has not yet set in. A disintegrating clot and dark haemolysed blood in the left ventricle is seen when an animal has been dead for 24 hours or more. This indicates that rigor mortis has occurred and that extensive post-mortem changes can be expected.

Fresh Carcass	Early Decomposition
	
Advanced Decomposition	**Skeletonization**
	

5. Forensic entomology: Forensic entomology intends to establish the time of death or NI by precisely showing how long the carcass has actually been exposed in the environment. Identification of the different species of insects and stages there off (e.g. eggs, larvae, pupae, maggots, flies and beetles) which are attracted to carcass are generally used for this purpose. Furthermore, insects may serve as important alternative species for toxicological analysis in cases where tissue samples are not available for this purpose (Verma and Paul, 2013; Bhat et al., 2011; Jadav & Sate, 2015)

The two most important species in determining NI are flies (Diptera) and beetles (Coleoptera). Diptera are the first insects to be attracted to and to colonize decomposing remains. It is the Dipteran larvae (maggots), which are responsible for much of the removal of decaying tissue. Following this initial stage and after the remains have dried out, most of the other insects, notably the beetles become involved in the process. The diversity and occurrence of insects on a carcass have been effectively documented by Jadav and Sate, (2015) and the details are provided below.

Insect species	Family	Sequence of occurrence on carcass
Sarcophaga lineatocollis Macquart	Sarcophagidae	Within 6 hours, fresh stage
Stomoxy scalcitrans Linnaeus	Muscidae	Within 6 hours, fresh stage
Chrysomya rufifacies Macquart	Calliphoridae	After 24 hours, bloated stage
Lucilia sericata Meigen	Calliphoridae	After 24 hours, bloated stage
Calliphora vicina Robineau- Desvoidy	Calliphoridae	After 24 hours, bloated stage
Necrophila rufithorax Selys	Silphidae	After 2-3 days
Dermestes maculatus (De Geer)	Dermestidae	At decay and dry stage
Necrobia rufipes (Fabricius)	Cleridae	After 2-3 days
Creophilus sp.	Staphilinidae	After 3-4 days
Hister sp.	Histeridae	After 3-4 days
Saprinus sp.	Histeridae	After 3-4 days

The growth rate of the maggots can be affected by changes in the temperature, geographic location, exposure to sun or shade, time of day and season, humidity, and rain (Hogon, 1999). As it is unlikely that a qualified forensic entomologist will actually be present on site for collection and documentation activities, it is therefore essential that the field veterinarians are well versed with various aspects of entomological documentation and collection procedures provided by Byrd et al., (2001).

6. Other relevant information: Additional information including nutritional status, presence of external injuries or marks should also be collected. All mucous membranes, including oral, nasal, conjunctiva, anus, vulva or prepucial mucus membranes should be thoroughly examined for any discoloration, discharges and presence of any abnormalities.

7. Classifying wounds: Wounds are known to act as either contributing factor or sometimes even primary cause of mortality in wild animals. A detailed inspection of the wound can lead to conclusive diagnosis in wide variety of cases, such as death due to gunshot, electrocution or natural mortality due to wound sustained from other tiger/ carnivore or prey species. A preliminary step in this process is to differentiate ante-mortem injuries from postmortem injuries. Major differences between the two are provided below.

Ante – mortem wounds	Post – mortem wounds
Evidence of copious hemorrhage	Hemorrhage minimal or absent
Wound edges gape due to normal elasticity and appear swollen and everted.	Edges do not gape due to loss of elasticity and appear in a closely approximated state.
Evidence of blood spurting	Spurting of blood does not occur
Firmly clotted blood	Blood is either clotted or liquefied
Tissue response might be observed if wound is old	Absence of tissue response

To aid in differential diagnosis, wounds should also be further classified based on their aetiology, location and type of injury, the details of which are provided below.

i. Bruise

External bruising is less common however skin and internal bruising from severe blunt force / trauma have frequently been encountered. These may result from vehicular collissions or when animal has been struck by blunt articles).

ii. Abrasion

These wounds result from friction applied approximately parallel to the skin's external surface. These are characterized by removal of variable amounts of the epidermis, dermis and hypodermis. Abrasions are typically superficial, trivial injuries, which bleed minimally and heal quickly leaving no scar.

iii. Puncture wound

A puncture wound has a depth greater than its length on the skin surface. Based on thickness and penetration, they are classified as either perforation wound (having both an entrance and an exit) or a penetrating wound (that has only an entrance).

iv. Incised wound

An incised wound is a breach of the skin resulting from contact with a clean and sharp edge objects. Penetration of full thickness of the skin is usual, but shallow, partial-thickness skin cuts can also occur.

v. Gunshot wound

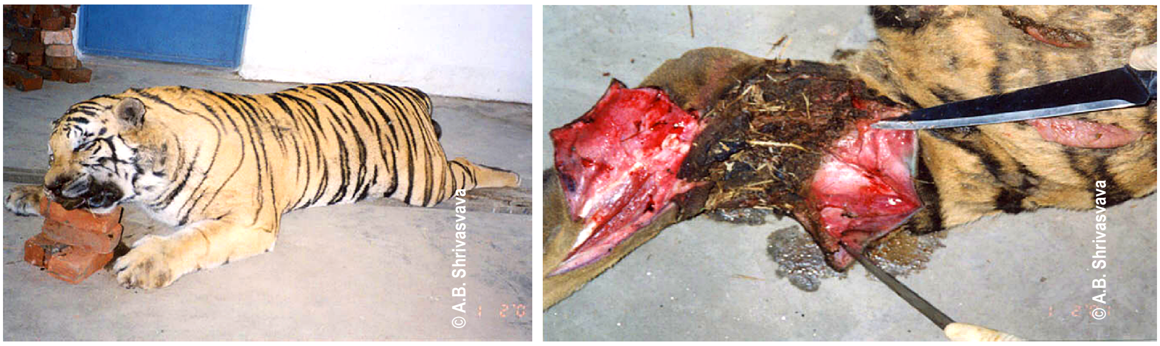
A gunshot wound is a penetrating wound where the projectile passes through the skin. The wound has an entrance and exit, with later being larger and more irregular than entry. The exit wound may be absent if the bullet gets trapped inside the body.

vi. Degloving wound

A degloving wound is a type of avulsion injury in which an extensive section of skin is completely torn off the underlying tissue. Degloving injuries typically occur when an animal is pushed or dragged by a moving vehicle or when an animal is trapped in snare/jaw trap, tries to free it selves by haphazardly pulling its trapped leg.

vii. Burns

Burn injuries may result from electric current passing through the body. Very often, a blister or burn, similar to the shape of the conductor (wire or fence) is seen at the contact site, confirming the diagnosis.



Internal examination

Though there is no single protocol applicable in all situations (as carcasses are usually found in varied state of decomposition and may be even incomplete due to scavenging), efforts should be made to use the opportunity to carry out as comprehensive post mortem examination as possible. It should include detailed examination of each organ system with proper recording of information as per the format provided. The format provided in the report has been adapted from the NTCA's SOP and includes minor additions that further support better information retrieval. Due emphasis has been given on proper sampling, preservation and transport. The format duly modified from existing format (NTCA) for recording of information during the post mortem examination is provided below:

RECORD OF NECROPSY EXAMINATION

Species: ***Panthera tigris tigris*** **Date:**
Common name: Bengal Tiger

A. LOCATION & EVENT INFORMATION

Protected Area/ Nearest Protected Area:		
If Inside Protected Area		**If Outside PA Protected Area**
Latitude: Longitude:		Latitude: Longitude:
Compartment:		Village:
Beat:		Tehsil:
Range:		District:

Date and time of Necropsy	Date: Time:	Estimated date and time of mortality	Date: Time:	Basis of estimation
Time of carcass acquisition by officials:		Time of carcass disposal:		
Ambient temperature:		Weather:		
Area/ Habitat description:				

B. ANIMAL IDENTIFICATION INFORMATION

Age group:	Juvenile (≤ 1 Year) ☐	Sub adult (1 – 3 years) ☐		
	Adult (3 – 10 years) ☐	Geriatric (≥ 10 years) ☐		
Sex:	Male ☐	Female ☐	Uncertain ☐	
UTID*:		Local ID:	Unidentified ☐	

*Permanent National ID as per "protocols for the establishment of a national repository of camera trap photogrphs of tigers".

C. CLINICAL AND PATHOLOGICAL OBSERVATIONS

I. Brief History

1. Medical history before death (if any):

2. Relevant observations around carcass:

II. Vital Measurements

1. Right fore paw dimensions:	Length X Width ……cm X……cm		
2. Left fore paw dimension:	Length X Width ……cm X……cm		
3. Canine dimensions:	Upper Right …….cm	Upper Left ……cm	Missing I Broken UR ☐ ☐ UL ☐ ☐ LR ☐ ☐ LL ☐ ☐
	Lower Right …….cm	Lower Left ……cm	
Gum Line recession:	Upper Right …… mm	Upper Left …….mm	
4. Inter canine width:	Upper …..……..cm	Lower …..……..cm	
Morphometric Measurements (Columns below to be filled only if carcass is fresh (Not bloated/putrified)			
5. Body Weight	………..kg		
6. Body measurements	Body length (Nose tip to base of tail) …….cm	Tail length……….cm	
	Chest girth …….cm	Neck Girth………..cm	
	Shoulder height….cm	Hind leg ………….cm	

III. External Observation

Rigor mortis:	Absent ☐	Setting in ☐	Complete ☐	Passing off ☐
Carcass condition:	Fresh ☐	Refrigriated ☐	Decomposed ☐	Incomplete ☐
State of Decomposition:	Fresh ☐	Bloated ☐	Putrified ☐	Skeletonised ☐
Physical condition:	Normal ☐	Obese ☐	Lean ☐	Emaciated ☐
External wounds:	Absent ☐	Ante-mortem ☐	Postmortem ☐	
Wounds (if present):	Bruice ☐	Abbresion ☐	Puncture ☐	Incision ☐
	Gunshot ☐	Blunt force ☐	Degloving ☐	Burns ☐
Wound Healing status (if present):	Fresh ☐	Infected ☐	Healing ☐	Healed ☐
Fractures:				
Detailed description of injuries (if present):				
Result of metal detector scanning:				
External orifices:		**Mucous membrane:**		

IV. Internal Examination

System		Appearance, color and observations
A. SUBCUTANEOUS TISSUE		
B. BODY CAVITIES 1. Position of visceral organs 2. Peritoneal Cavity 3. Pleural cavity and Pleura 4. If fluid present in the Peritoneum or thorax: Color, transparency and amount		
C. RESPIRATORY SYSTEM 1. Larynx 2. Trachea 3. Lung parenchyma 4. Diaphragm 5. Lymph nodes		
D. CIRCULATORY & LYMPHATIC SYSTEM 1. Pericardial SAC 2. Heart Muscle 3. Heart Chambers a. Right Atrium b. Left Atrium c. Right Ventricle d. Left Ventricle 4. Blood Vessels 5. Spleen 6. Lymph nodes		
E. HEPATIC SYSTEM 1. Liver 2. Liver Parenchyma 3. Gall Bladder		
F. DIGESTIVE SYSTEM		
1. Pharynx 2. Esophagus		
3. Stomach	Cardiac zone	
	Fundus	
	Pylorus	
	Contents	
4. Small intestine	Duodenum	
	Jejunum	
	Ileum	
	Contents	
5. Large intestine	Ceacum	
	Colon	
	Rectum	
	Contents	

G. UROGENITAL			
1. Urinary Bladder			
2. Kidneys		Left	Right
Capsule:			
Cortex:			
Medulla:			
3. REPRODUCTIVE ORGANS	Testes ☐		
	Ovary ☐		
	Penis ☐		
	Uterus ☐		
H. LYMPH GLANDS			
I. HEAD 1. Buccal Cavity 2. Nasal Orifices 3. Tongue 4. Submandibular/ Maxillary lymph nodes			
I. NERVOUS SYSTEM 1. Brain 2. Spinal cord			
J. SKELETAL SYSTEM			

V. Record sheet for parasites

Body Region	Parasite Type	Yes / No	Location	Description
Subcutaneous tissue/ Muscles	1. Worms 2. Cysts 3. Other			
Body cavities	1. Cysts 2. Worms			
Respiratory system	1. Lungworm 2. Cysts 3. Other			
Liver and Gall bladder	1. Flukes 2. Tape worms 3. Round worms 4. Cysts			
Heart and blood vessels	1. Worms 2. Blood flukes 3. Cysts			
Digestive system	1. Tapeworms 2. Round worms 3. Cysts			
Urogenital organs	1. Worms 2. Others			
External parasites	1. Tick 2. Flea 3. Lice 4. Mites			

VI. SUMMARY

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PROVISIONAL DIAGNOSIS: ....

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PLACE:

DATE :

SIGNATURE:

NAME :

DESIGNATION:

ADDRESS:

PLACE:

DATE :

SIGNATURE:

NAME :

DESIGNATION:

ADDRESS:

VII. Checklist for specimen collection for laboratory Analysis

S. No	Examination required	Preservative used	Specimen	Designated laboratory

PLACE:

DATE :

SIGNATURE:

NAME :

DESIGNATION:

ADDRESS

VIII. Photographs

Whole carcass as observed before necropsy	
Left lateral view	
Right Lateral View	
Oral cavity (Close up view)	
Gross lesion of major visceral organs (Heart, lungs, liver, spleen, GI tract, kidney, brain etc (including lymph nodes)	

Photographic records: Photographs serve as a backup to the written descriptions on the necropsy record. They also allow pathologists to assess gross lesions/observations in relation to samples sent for analyses. It is worthwhile to take at least one full body photograph of both the left and right flank of the carcass prior to initiating PM as it would aid in identification of the dead tiger based on stripe pattern. Additionally, photograph all the specific lesions, (the entire organ, with reference to its anatomical location) as well as a closer shot of the particular lesion (preferably on the cutting board, with a scale to depict details of the abnormality). These need to be part of the PM report.

Sample collection: Determination of the cause of death in wild animals is often difficult and requires laboratory support. Proper sampling is crucial and integral part of the any mortality investigation. All the specimens must be collected with utmost precaution, preserved and packed in suitable conditions, appropriately labelled, and transported to the designated laboratory by the fastest route possible.

As the quality of samples collected diminishes with the progression of decomposition and creating greater uncertainty with results, it is important to prioritize sample collection, based on the condition of carcass at the time of sample collection.

- Samples from fresh carcass can be used for histology, cytology, microbiology (culture and PCR), virology (tissue), parasitology, toxicology, and genetics.
- Samples from moderately decomposed carcass (early decomposition) can be used for histology (limited value), microbiology (PCR), virology (PCR), parasitology, toxicology, and genetics.
- Samples from carcass with advanced decomposition can be used for histology (limited/ absent) virology (PCR), and genetics.
- Mummified/Skeletal Remains can be used for toxicology (limited), and genetics.

Examination	Type of Specimen	Preservation Method	Type of Container	Comments
Histopathology	Tissues and lesions	10% buffered formalin	Wide mouthed, Leak-proof glass or plastic	Sections no more than ¼ inch thick. Ratio of 10:1 formalin to tissue. Storage at room temperature.
Haematology	Whole blood in anticoagulant	Refrigeration	Glass or plastic tubes	Gently rotate tubes to mix blood with anticoagulant. Generally short storage
Serology	Blood and Serum	Refrigeration or freezing of serum/ portion of blood or in merthiolate	Clean, dry glass or plastic vials	Handle gently to avoid rupture of red cells. Transfer serum to separate container before freezing.
Virology	Organs, tissue, lesions or body fluids	50% glycerol saline or Phosphate Buffer saline (PBS)/Hank's balanced salt solution	Sterile plastic/glass containers	Care to avoid contamination is critical. Appropriate sampling varies with different diseases
Bacteriology	Whole blood, Organs, tissue, lesions, or body fluids, swabs	Usually refrigeration/on ice	Sterile plastic/glass containers	Care to avoid contamination is critical. Appropriate sampling varies with different diseases

Examination	Type of Specimen	Preservation Method	Type of Container	Comments
Mycology	Hair sample & skin scraping	At room temperature	Sterile plastic/glass containers	Care to avoid contamination is critical. Appropriate sampling varies with different diseases
	Tissues/Deep skin scrap	Usually refrigeration or freezing		
Parasitology	Worms	5% formalin	Glass or plastic container	Storage at room temperature
	External parasites	70% alcohol or 5% formalin	Glass or plastic container	Storage at room temperature
	Blood parasites	Air dried blood films or whole blood in anticoagulant	Glass slides or tubes	Blood slides stored at room temperature. Tubes of whole blood refrigerated
Toxicology	Organs, fat, blood and ingesta or suspected contaminated foods	Refrigeration or freezing, Methanol, saturated salt solution	Clean glass, plastic, or metal foil	Accurate records are critical. Appropriate sampling varies with suspected toxin.
	larvae, maggots, pupa and other entomological samples (In highly putrefied carcasses)	Refrigeration or freezing, Methanol, saturated salt solution	Clean glass, plastic containers	Accurate records are critical. Appropriate sampling varies with suspected toxin.
Forensic entomology	larvae, maggots, pupa and other entomological samples	80% ethyl alcohol	Clean, airtight glass or plastic containers	Associated habitat, photographic and metrological data should accompany samples
Ballistics	Wound swab (collected with cotton tip applicator))	Cotton tip applicator should be moistened with isopropyl alcohol or 5% nitric acid before collection.	Airtight zip lock pouches.	Accurate records and photo documentation is critical.
	Projectiles (Shrapnel, bullet fragments)	Without any preservative		
Genetics	Tissue, bone, hair samples.	90 % ethanol or Silica gel	Airtight containers	Storage at room temperature

All specimens should be clearly numbered and labeled. All relevant information should accompany the specimens and recorded appropriately in designated section of the Necropsy Record form.

Carcass Disposal: After collection of all the required samples, the carcass should be immediately disposed as per "Standard operating procedure for disposing the tiger/ leopard carcass/body parts" vide advisories of the Ministry of Environment & Forests/ Project Tiger/ NTCA on the subject (Advisory No: 1-60/89-WL I dated 04-11-1994 from the Addl. IGF (wildlife) Ministry of Environment and Forests). Available at http://projecttiger.nic.in/writereaddata/cms/sop_carcass-disposa25feb2013.pdf.

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Necropsy Observations in Poisoning Cases

In a case of suspected poisoning, specimens should be collected in duplicates and placed in sealed containers, with suitable preservatives (as elaborated in ANNEXURE 1) taking due consideration of legalities. Further, detailed necropsy examination should be conducted and pathological observations made should be recorded accordingly. Photographs of the affected animals and the surroundings should be taken for future reference. In all legal cases, an accurately documented chain of custody of specimens and a thorough record of the investigation and related analyses and other diagnostic methods and results must be maintained (Cheeran, 2007).

Observations made during some commonly used poisons are as follows.

ORGANOCHLORINE COMPOUNDS

Organochlorine Insecticides (also known as chlorinated hydrocarbons) are mainly characterized by, presence of carbon (organo-), chlorine and hydrogen and sometimes oxygen atoms including a number of C-Cl bonds. These are contact insecticides and ectoparasiticides, which act on central nervous system, producing hyperactivity and tremor and occasionally convulsions.

Examples: DDT (*Dichloro Diphenyl Trichloroethane*), HCH (*hexachlorocyclohexane*), aldrin, dieldrin, endosulphan, etc.

Necropsy findings: Cyanosis**;** blood tinged froth in the respiratory system**;** pulmonary oedema**;** congestion in the lungs, liver and kidney**;** and dead maggots/ flies in and around fresh carcass (Cheeran, 2007).

Material required for laboratory analysis: Gut contents, fat, kidney, liver, brain and suspected poisoned prey carcass (if any) should be sent for laboratory analysis.

Preservative: Freezing is the preferred way of preservation. Alternatively, 50% ethanol (1 ml/g/tissue) or Saturated salt solution (specimen should be completely submerged) can be used in case freezing facilities are not available

ORGANOPHOSPHORUS COMPOUNDS

Organophosphorous insecticides (often refer to as organo phosphates) are neutral ester or amide derivatives of phosphorous acids carrying a phosphoryl (P-O) or thiophosphoryl (P-S) group. They are commonly used as insecticides, acaricides, soil nematicides, fungicides and in a variety of similar products and act by inhibiting cholinesterase activity, causing acute muscarinic manifestations.

Examples: Chlorfenvinphos, chlorpyriphos, coumaphos, demeton, diazinon, dichlorvos, dimethoate, ecothiophate, fenthion, malathion, methyl parathion, Schradan, andtrichlorfon.

Necropsy findings: Brick red coloured visible mucus membrane; pulmonary oedema, congestion, cyanosis, frothy discharges in trachea and bronchial trees; haemorrhages and oedema of the heart, bowel as well as other organs; cerebral oedema; and necrotic patches on the skeletal muscles. The intestinal tract will be usually dilated and fluid filled, with partially digested or undigested meat (Cheeran, 2007; Kalaivanan et al., 2011; Allwin et al., 2015).

Material required for laboratory analysis: Gut contents, visceral organs and suspected poisoned prey carcass (if any) should be sent for laboratory analysis.

Preservative: Freezing is the preferred way of preservation. Alternatively, 50% ethanol (1 ml/g/tissue) or Saturated salt solution (specimen should be completely submerged) can be used in case freezing facilities are not available

CARBAMATE COMPOUNDS

Carbamate are anticholinesterase insecticides and are synthetic derivatives of physostigmine, also known as eserine, which is a principle alkaloid of plant, *Physostigma benenosum*, calabar bean. These are are commonly used to control or destroy insects, arachnids and nematodes.

Examples: Carbaryl, Methomyl, Propoxur, Aldicarb.

Necropsy findings: Generalized congestion and cyanosis, symptoms similar to organophosphorus poisoning (Cheeran, 2007; Venkataramanan et al., 2008).

Material required for laboratory analysis: Gut contents, visceral organs and suspected poisoned prey carcass (if any) should be sent for laboratory analysis.

Preservative: Freezing is the preferred way of preservation. Alternatively, 50% ethanol (1 ml/g/tissue) or Saturated salt solution (specimen should be completely submerged) can be used in case freezing facilities are not available

PHOSPHORUS

Yellow phosphorus is used as a common ingredient in rodenticides and is easily available in the market. It is a protoplasmic poison, strong irritant, corrosive and has a necrotising effect on the stomach mucosa.

Necropsy findings: The gastric contents will have typical garlic odour and could be phosphorescent; signs of severe gastroenteritis, fatty liver, multiple hemorrhages and black tarry blood that does not clot; signs of severe hepatitis, evidence of jaundice and renal damage could be present (Cheeran, 2007).

Material required for laboratory analysis: Gut contents, visceral organs and suspected poisoned prey carcass (if any) should be sent for laboratory analysis.

Preservative: Freezing is the preferred way of preservation. Alternatively, 50% ethanol (1 ml/g/tissue) or Saturated salt solution (specimen should be completely submerged) can be used in case freezing facilities are not available

ZINC PHOSPHIDE

Zinc phosphide is a common ingredient used in rodenticides. Upon ingestion, it reacts with dilute acids in the gastrointestinal tract, producing phosphine which enters the blood stream to cause toxicity.

Necropsy findings: The gastric contents will have a characteristic “dead fish” or acetylene odour due to emission of phosphine gas; hemorrhagic gastroenteritis, generalized visceral congestion and pulmonary oedema may also be present (Cheeran, 2007).

Material required for laboratory analysis: Gut contents, visceral organs and suspected poisoned prey carcass (if any) should be sent for laboratory analysis.

Preservative: Freezing is the preferred way of preservation. Alternatively, 50% ethanol (1 ml/g/tissue) or Saturated salt solution (specimen should be completely submerged) can be used incase freezing facilities are not available

STRYCHNINE

Strychnine is an alkaloid obtained from the seeds of the tree *Strychnos nuxvomica* (or seeds of a climbing shrub *Strychnos ignati*). It inhibits competitively and reversibly the inhibitory neurotransmitter glycine in the spinal cord and the medulla and causes death by asphyxia combined with acidosis.

Necropsy findings: Rigor mortis sets in fast due to muscular contractions; cyanosis and asphyxia, subcutaneous or intramuscular hemorrhages may be seen (Cheeran, 2007).

Material required for laboratory analysis: Gut contents, visceral organs and suspected poisoned prey carcass (if any) should be sent for laboratory analysis.

Preservative: Freezing is the preferred way of preservation. Alternatively, 50% ethanol (1 ml/g/tissue) or Saturated salt solution (specimen should be completely submerged) can be used in case freezing facilities are not available

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Annexure 3

Institutional support

Institutional support: Necropsy sample analysis needs sophisticated laboratories, which are often not available with individual tiger reserves/protected areas. Thus, to increase the chances of arriving at a conclusive diagnosis, each tiger reserve/protected areas should have collaboration with recognized laboratory facilities in advance. A list of such institutions is listed below.

I. Veterinary Council of India (VCI) recognized Veterinary Institutes

S. No	State	Name and address
1.	Andhra Pradesh & Telangana	College of Veterinary Science, Hyderabad Address: Rajendranagar mandal, Hyderabad – 500030, Telangana. Phone : 040-24002114 Fax : 040-24002114 E-mail : NA
		College of Veterinary Science, Tirupati Address: Milk factory premises, Tirupati – 517502, Andhra Pradesh. Phone : 0877 2249932 Fax : 0877 2249563 E - mail : NA
		NTR College of Veterinary Science, Gannavaram Address: Buddhavaram Road, Krishna, Gannavaram, Andhra Pradesh 521101 Phone : 08676-253781 Fax : 08676-252335 E - mail : NA
2.	Assam	College of Veterinary Science, Guwahati Address: Guwahati-Shillong Rd, Resham Nagar, Khanapara, Guwahati, 781022, Assam Phone : 0361-2337700 E-mail : cvsguwahati.btisnet@nic.in
3.	Bihar	Bihar Veterinary College, Patna Address: Near Patna Airport, Patna, Bihar 800014 Phone : 0612-2226644, 2222231 Fax : 0612-2222231 E-Mail : principalbvc@gmail.com
4.	Chhattisgarh .	College of Veterinary Science & Animal Husbandry, Durg Address: Anjora Village, Near Shivnadh River, Durg - 491001, Chhattisgarh Phone : 094076 69030 Fax : NA E-Mail : drscgkv@gmail.com

S. No	State	Name and address
5.	Gujarat	College of Veterinary Science and Animal Husbandry, Anand Address: Anand Agricultural University, Anand - 388110, Gujarat. Phone : 02692-261486 Fax : NA E-Mail : deanvet@aau.in
		College of Veterinary Science and Animal Husbandry, Sardarkrushinagar, University Bhavan, SDAU, Sardarkrushinagar-385506. District Banaskantha. Gujarat. Phone : 02748 - 278226 Fax : 02748 - 278234 E-Mail : registrar@sdau.edu.in
		College of Veterinary Science and Animal Husbandry, Navsari Address: College of Veterinary Science & Animal Husbandary, Navsari Agricultural University, Navsari-396 450, Gujarat Phone : 02637 - 282299 Fax : 02637 - 282964 E-Mail : deanvet@nau.in
		College of Veterinary Science and Animal Husbandry, Junagadh Address: College of Veterinary Science and Animal Husbandry, Junagadh, Junagadh Agricultural University Motibaug, Junagadh- 362001 Gujarat. Phone : 0285 -2670722 Fax : 0285-2670722 E-Mail : covsah@jau.in
6.	Haryana	College of Veterinary Science, Hisar Address: College of Veterinary Science, Hisar Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar-125001, Haryana. Phone : 01662- 256101 Fax : NA E-Mail : dcovs@luvas.edu.in
7.	Himachal Pradesh	Dr. G.C. Negi College of Veterinary and Animal Sciences, Palampur. Address: Dr. G.C. Negi College of Veterinary and Animal Sciences CSK Himachal Pradesh Krishi Vishwavidyalay, NH20, Holta, Palampur – 176062, Himachal Pradesh Phone : 01894-230327 Fax : 01894-230327 E-Mail : dcovas@hillagric.ac.in
8.	Jammu & Kashmir	Faculty of Veterinary Sciences & Animal Husbandry, Srinagar. Address: Faculty of Veterinary Sciences & Animal Husbandry Sher-e Kashmir University of Agricultural Sciences & Technology, Jammu & Kashmir, Shalimar, Srinagar – 190025, Jammu and Kashmir. Phone : 0194 - 2262207

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9.	Jharkhand	Ranchi College of Veterinary Science and Animal Husbandry, Ranchi Address: Birsa Agricultural University, Kanke, Ranchi – 834006, Jharkhand Phone : 0651-2450832 Fax : 0651-2450850
10.	Karnataka	Veterinary College Hebbal, Bangalore Address: Bellary Rd, Opposite To CBI Office, Hebbal, Bengaluru – 560024, Karnataka Phone : 080-23411483, 23410509 E-mail : deanvch@gmail.com
		Veterinary College Nandinagar, Bidar Address: State Highway 15, Nandinagar, Bidar – 585401, Karnataka Phone : 08482-245108, 245106-8, 245009 Fax :08482 – 245108
		Veterinary College, Hassan Address: Gokula Campus, Vidyanagar, Hassan - 573 202, Karnataka Phone : 08172-245373 E-mail : deanhvc@gmail.com
		Veterinary College, Shimoga Address: Vinobanagar, Shivamogga - 577 204, Karnataka Phone : 08182-320920 Fax :08182-233657 E-mail : vcsdean@gmail.com
11.	Kerala	College of Veterinary & Animal Sciences, Thrissur Address: PB No. 20, Mannuthy, Thrissur - 680651, Kerala Phone : 09446445100 Fax : NA E-mail : deanvetmty@kvasu.ac.in
		College of Veterinary and Animal Sciences, Pookode Address: Kerala Veterinary and Animal Sciences University, Lakkidi Post, Pookode – 673576, Kerala Phone :04936-256991 Fax : NA E-mail : deanvetpkt@kvasu.ac.in
12.	Madhya Pradesh	College of Veterinary Science & Animal Husbandry, Jabalpur Address: Indira Gandhi Marg, Panagar, South Civil Lines, Jabalpur - 482001, Madhya Pradesh Phone : 0761-2620783, Fax : 0761-2620783 E-mail : vcnduvs@gmail.com

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		College of Veterinary Science & Animal Husbandry, Mhow Address: P.O. Rasalpura, Mhow – 453446, Madhya Pradesh Phone : 07324-276655, (O) Email : deanvetmhow@gmail.com
13.	Maharashtra	College of Veterinary & Animal Sciences, Parbhani Address: College of Veterinary & Animal Sciences, Parbhani-431402, Maharashtra Phone : 02452-233375 Fax : 02452-226188 E - mail : NA
		Nagpur Veterinary College, Nagpur Address: Seminary Hills, Nagpur -440006, Maharastra Phone : NA Fax :0712-2510883 E mail : dean_nvc1@rediffmail.com
		Bombay Veterinary College, Mumbai Address: BVC Campus Road, Parel, Mumbai – 400012, Maharashtra Phone : 022 24157020, 24162552,24131180 Fax : 022-24172301 E - mail : NA
		College of Veterinary & Animal Sciences, Udgir Address: Udgir-413517, Dist- Latur, Maharashtra Phone :02385- 257448, 256630 Fax :02385- 257448 E - mail : NA
		K.N.P. College of Veterinary Sciences, Satara Address: Krantisinh Nana Patil College of Veterinary Science, Shirval – 412801, Dist. Satara, Maharashtra. Phone : 02169 244 227, Fax : 02169 244 243 E- mail : knpcovs@mafsu.in
14.	Mizoram	College of Veterinary Science & Animal Husbandry, Aizawl, Mizoram Address: Zuangtui - Selesih Rd, Aizawl – 796014, Mizoram. Phone : 0389-2361748 Fax : NA E-mail : dean@cvsccauaizawl.org
15.	Odisha	College of Veterinary Science and Animal Husbandry, Bhubaneswar Address: OUAT Campus, Siripur Square, Near Surya Nagar Post Office, Siripur, Unit 8, Bhubaneswar – 751003, Odisha. Phone : 0674-2397732 Fax : NA E -mail : contact@ovcbbsr.in

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16.	Puducherry	Rajiv Gandhi College of Veterinary & Animal Sciences, Address: Rajiv Gandhi Institute of Veterinary Education & Research , Vazhudhavur Road, Kurumbapet - 605 009, Puducherry. Phone : 0413 - 2273001 Fax : NA E-Mail : ragacovaspvcs1994@gmail.com
17	Punjab	College of Veterinary Science, Ludhiana Address: Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana Road, A Block, Aggar Nagar, Ludhiana – 141012, Punjab. Phone : 0161 - 2414020 Fax : 0161 - 2400822 E-Mail : deancovs@gadvasu.in
		Khalsa College of Veterinary and Animal Sciences, Amritsar Address: Guru Angad Dev Veterinary and Animal Sciences University, Ram Tirath Rd, Makka Singh Colony, Amritsar – 143001, Punjab. Phone : 0183 - 6051012 Fax : NA E-Mail : kcvas_amritsar@yahoo.com
18.	Rajasthan	College of Veterinary and Animal Science, Bikaner Address: Vijay Bhawan Palace Complex, Veterinary University Road, Near Deen Dayal Upadhyay Circle, Bikaner – 334001, Rajasthan Phone : 0151-2111556 Fax : NA E-mail : websiterajuvas@gmail.com
19.	Tamil Nadu	Madras Veterinary College, Chennai. Address: Vepery High Road, Vepery, Chennai – 600007, Tamil Nadu Phone : 0442-5304000 Fax : 0442-536 2787 E-mail : deanmvc@tanuvas.org.in
		Veterinary College and Research Institute, Namakkal Address: Salem - Namakkal - Trichy Rd, Thillaipuram, Namakkal - 637002, Tamil Nadu. Phone : NA Fax : NA E-mail : deanvcri@tanuvas.org.in
20.	Uttar Pradesh	College of Veterinary Science and Animal Husbandry, Faizabad Address: Narendra Dev University of Agriculture & Technology Kumarganj, Faizabad - 224 229, Uttar Pradesh Phone : 05270 262002 Fax : NA E - mail : NA
		College of Veterinary Science and Animal Husbandry, Mathura Address: UP Pandit Deen Dayal Upadhyaya pashu Chikitsa Vigyan Vishwavidyalaya, Near DM office, Mathura Cantonment, Mathura -

S. No	State	Name and address
		281001. Uttar Pradesh Phone : 0565-2471178 Fax : 0565-2470819 E-mail : registrarduvasu@gmail.com
21.	Uttarakhand	College of Veterinary Sciences, Pantnagar. Address: G.B. Pant University of Agriculture and Technology Pantnagar – 263145, Uttarakhand Phone : 05944-233347 Fax : 05944-233473 E-mail : dean.vaspgr@gmail.com
22.	West Bengal	Faculty of Veterinary & Animal Sciences , Kolkata Address: West Bengal University of Animal and Fishery Sciences. 37 & 68 Kshudiram Bose Sarani, Kolkata - 700 037, West Bengal Phone : 033-25563396 Fax : 033-25563396 E- mail : NA

II. Specialized Veterinary Institutes offering wildlife health, disease diagnostic and forensic services

Sn. No	Name and address
1.	Centre for Wildlife Conservation, Management and Disease Surveillance, Bareilly. Address: Centre for Wildlife Conservation, Management and Disease Surveillance Indian Veterinary Research Institute, Izatnagar – 243122, Bareilly, Uttar Pradesh Phone : +91 581 2300587, +91 581 2586292 Fax : 0581-2303284 E-mail : aksharmaivri@rediffmail.com
2.	Centre for Wildlife Forensic and Health, Jabalpur. Address: Indira Gandhi Marg, Panagar, South Civil Lines, Jabalpur, Madhya Pradesh 482001 Phone : 0761 - 2627150 Fax : 0761-2620783 E-mail : drabshrivastav@yahoo.co.in
3.	Institute of Wildlife Veterinary Research, Kodagu Address: Institute of Wildlife Veterinary Research, Karnataka Veterinary, Animal and Fisheries Sciences University, Doddaluvara - 571 232, Kodagu, Karnataka. Phone : 08276- 278992 Fax : NA E-mail : diriwvr@gmail.com

Sn. No	Name and address
4.	The Department of Wildlife Science, Chennai. Address: Madras Veterinary College, Chennai. Vepery High Road, Vepery, Chennai, Tamil Nadu 600007 Phone : 0442-5304000 Fax : 0442-536 2787 E-mail : deanmvc@tanuvas.org.in
5.	Centre for Wildlife Health, Bhubaneswar. Address: OUAT Campus, Siripur Square, Near Surya Nagar Post Office, Siripur, Unit 8, Bhubaneswar, Odisha 751003. Phone : 0674-2397732 Fax : NA E -mail : contact@ovcbbsr.in
6.	Wildlife Health Centre, Anand Address: College of Veterinary Science and Animal Husbandry, Anand Anand Agricultural University, Anand - 388110. Gujarat. Phone : Ph.+91-2692-261486 Fax : NA E-mail : deanvet@aau.in
7.	Center for Wildlife Health, Chhattisgarh Address: College of Veterinary Science & Animal Husbandry ,Durg Anjora Village, Near Shivnadh River, Durg, Chhattisgarh 491001 Phone : 094076 69030 Fax : NA E- mail : drscgkv@gmail.com
8.	Institute of Animal Health & Veterinary Biologicals, Bengaluru Address: Bellary Rd, Vinayakanagar, Bengaluru – 560024, Karnataka. Phone : 080 2341 1502 Fax : NA E-mail : info@iahvb.com
9.	Institute of Animal Health & Veterinary Biologicals, Kolkata Address: Institute of Animal Health & Veterinary Biologicals, 37, Belgachia Road - 700 037, Kolkata Phone : 02223-6236 Fax : 02556-5476 E - mail : iahvb.kolkata@rediffmail.com

III. Central Veterinary Laboratories and Research Stations

Sn. No	Name and address
1.	Indian Veterinary Research Institute Address: Indian Veterinary Research Institute, Izatnagar-243122, Uttar Pradesh Phone : 0581-2300096 Fax : 0581-2303284 E - mail : dirivri@ivri.up.nic.in
2.	IVRI Bengaluru Campus, Hebbal, Bengaluru-560024, Karnataka Address: IVRI Bengaluru Campus, Hebbal, Bengaluru-560024, Karnataka Phone : 081-23412835 Fax : 081-23412509 E - mail : idivri@dataone.in
3.	IVRI Eastern Regional Station Address: 37, Belgachia Road, Kolkata - 700037, West Bengal Phone : 033-25286358, 25582965 Fax : 033-25565725 E – mail: NA
4.	High Security Animal Disease Laboratory Address: Kokta Road, Anand Nagar, Bhopal-462021, Madhya Pradesh Phone : 0755-2759204 Fax : 0755-2758842 E - mail: scd211@yahoo.co.in
5.	IVRI Mukteshwar Campus Address: IVRI Mukteshwar Campus Mukteshwar- Kumaon, Nainital-Uttrakhand Phone : 05942-286348, 286346 Fax : 05942-286347 E - mail : NA
6.	Project Directorate on Animal Disease Monitoring and Surveillance Address :PD-ADMAS, Hebbal, Banglore-560024, Karnataka Phone : 080-23412531, 23419576 Fax : 080-23415329 E - mail: pd_admas@rediffmail.com

For chemical and ballistic analysis, services of The Central Forensic Science Laboratories (CFSL), which are controlled by the Directorate of Forensic Science Services (DFSS) of the Ministry of Home Affairs, can be availed. There are seven such central forensic laboratories in India, at Hyderabad, Kolkata, Chandigarh, New Delhi, Guwahati, Bhopal and Pune.

The jurisdiction of these CFSL's (except for CFSL Delhi, which is controlled by CBI), vide MHA order number25020/61/13/FW/MHA is as follows:

Central Forensic Science Laboratory, Chandigarh Directorate of Forensic Science Services, Ministry of Home Affairs, Govt. of India Address: CFIs Complex, Sector – 36 A, Chandugarh, 160036 Phone : 0172- 2615068 Jurisdiction: 1. Jammu & Kashmir 2. Himachal Pradesh 3. Punjab 4. Chandigarh (UT) 5. Uttarakhand 6. Delhi & NCR 7. Haryana	**Central Forensic Science Laboratory, Bhopal** Directorate of Forensic Science Services, Ministry of Home Affairs, Govt. of India Address: Gomantika Parisar, Jawahar Chowk, North T.T. Nagar, Bhopal, 462003. Phone : 0755-2779657 Fax : 0755-2779658 Jurisdiction: 1. Madhya Pradesh 2. Uttar Pradesh 3. Rajasthan 4. Chhattisgarh
Central Forensic Science Laboratory, Hyderabad Directorate of Forensic Science Services, Ministry of Home Affairs, Govt. of India Address: Near Hyderabad Public School, Ramanthapur Colony Rd, Amberpet, Hyderabad, Telangana, 500013. Phone : 040-2703 0962, 27038429, 27035822 Fax : 040-2703 9281 Jurisdiction: 1. Andhra Pradesh & Telangana 2. Tamil Nadu 3. Karnataka 4. Kerala 5. Lakshadweep 6. Puducherry (UT)	**Central Forensic Science Laboratory, Guwahati** Directorate of Forensic Science Services, Ministry of Home Affairs, Govt. of India Address: H.No.16, Lachit Borpukhan Path, Tetelia PO Gotanagar, Guwahati, 781033. Phone : 0361-2571149 Fax : 0361-2571148 Jurisdiction: 1. Assam 2. Manipur 3. Mizoram 4. Meghalaya 5. Sikkim 6. Nagaland 7. Arunachal Pradesh 8. Tripura
Central Forensic Science Laboratory, Kolkata Directorate of Forensic Science Ministry of Home Affairs, Govt. of India Address: 30 Gorachand Road, Park Circus, Kolkata, 700014. Phone : 033-22843187, 22841638, 22840378 Fax : 22849442 Jurisdiction: 1. Orissa 2. Bihar 3. Jharkhand 4. West Bengal 5. Andaman & Nicobar islands	**Central Forensic Science Laboratory, Pune** Directorate of Forensic Science Ministry of Home Affairs, Govt. of India Address: 38/4, Krishna Complex Kharadi Bypass, Kharadi, Pune, 411014. Phone: 020-20261696, 20261698 Jurisdiction: 1. Maharashtra 2. Gujarat 3. Goa 4. Daman & Diu 5. Dadar & Nagar Haveli

(Available at http://www.dfs.nic.in/pdfs/1st.pdf. accessed May, 2016)

Disease events recorded in tigers (*Panthera tigris*)

Bacterial Diseases	Origin	Location
Anthrax	Captive	Skopje, Republic of Macedonia; and France (Hugh-Jones & De Vos 2002).
Colibacillosis	Captive	National Zoological Park, New Delhi (Char et al., 1986)
Hemorrhagic septicemia/ bronchopneumonia	Captive	Padmaja Naidu Himalayan Zoological Park, Darjeeling, West Bengal (Maity & Chakraborty, 1996), Nawab Wazid Ali Shah Prani Udyan , Uttar Pradesh (Arora, 1988 – 95)
Hemorrhagic septicemia	Free ranging	Terai forest division, Uttarakhand (Arora & Kumar, 1988)
Leptospirosis	Captive	Nawab Wazid Ali Shah Prani Udyan, Uttar Pradesh (Arora, 1984); Mahendra Chaudhary Zoological Park, Punjab (Singh, M. P., Pers. com)
	Free ranging	Location not specified (Arora, 1984)
Salmonellosis	Captive	Bannerghatta Biological Park, Karnataka (Shilpa et al., 2012)
Shigellosis	Captive	Assam State Zoo cum Botanical Garden , Assam (Boro et al., 1980), Bannerghatta Biological park, Karnataka (Zaki et. al., 1980)
Tuberculosis	Free ranging	Dudhwa National Park, Uttar pradesh (Arora, 2003)
	Captive	Sanjay Gandhi Jaivik Udyan, Bihar & Arignar Anna Zoological Park, Tamil Nadu (Arora, 2003a), Budapest Zoological and Botanical Garden, Hungary (Lantos et al., 2003); Gwangju Uchi Park Zoo, Republic of Korea (Cho et al., 2006).

Rickettsial Diseases	Origin	Location
Anaplasmosis	Captive	Nehru Zoological Park, Andhra Pradesh (Ahmed et al., 1990)
Ehrlichiosis	Captive	Sanjay Gandhi National Park, Maharashtra (Arora, 2003b)

Viral Diseases	Origin	Location
Avian Influenza	Captive	Suphanburi Zoo, Thailand (Keawcharoen et al., 2004, Thanawongnuwech et al., 2005); Phnom Tamao Wildlife Rescue Centre, Cambodia (Desvaux et al., 2009); Guangxzi zoo, China (EMPRES, 2015).
Canine Distemper	Captive	Wildlife Way station & Shambala Preserve, USA (Appel et al., 1994); Oregon, USA (Blythe et al., 1983), Zurich Zoo & private zoo or circuses, Switzerland (Myers et al., 1997), Zagreb Zoo, Croatia (Konjević et al., 2011), A safari style zoo, Japan (Nagao et al., 2012).
	Free ranging	Russian Far East (Goodrich et al., 2008, Quigley et al., 2010).
Feline Calicivirus	Captive	Potter Park Zoo, USA (Harrison et al., 2007). Bueng Cha-Wag Chalerm Prakeit Zoo, Thailand (Charoenyongyoo et al., 2008)
Feline Coronavirus	Captive	Manila Zoological and Botanical Gardens, Philippines (Suba et al., 2016)
	Free Ranging	Russian Far East (Goodrich et al., 2012)
Feline Immunodeficiency Virus	Captive	Cheyenne Mountain Zoo, USA (Barr et al., 1989)
Feline Panleukopenia	Captive	Nandankanan Zoological Park, Odisha (Rao et al., 1995); Zoological Garden, Thrissur Zoo or State Museum, Thrissur (George et al., 1990); Van Vihar National Park, Bhopal (Sharma, 1997), Lisbon Zoo, Portugal (Duarte et al., 2009); Zoological Society of London, UK (Cockburn, 1947).
Rabies	Free ranging	Nowgaon District, Assam in 1943; Saikowhaghat, Assam in 1950 (Burton, 1950).
	Captive	National Zoological Park, New Delhi (Arora, 2003c); Nandankanan Zoological Park, Odisha (Rao and Nayak, 1984).

Prion Diseases	Origin	Location
Feline Spongiform Encephalopathy	Captive	Great Britain (Kirkwood and Cunningham, 1999)

Fungal Diseases	Origin	Location
Coccidioidomycosis	Captive	The El Paso Zoo, USA (Helmick et al., 2006).
Microsporum canis	Captive	Tiger Haven Inc.: An exotic cat sanctuary, USA (Sykes et al.,2007)

Protozoan Diseases	Origin	Location
Babesiosis	Captive	National Zoological Park, New Delhi (Nagar et al., 1979); Bhagawan Birsa Biological Park, Jharkhand (Sinha et al. 2000), National Zoological Park , New Delhi (Khurana, 1969); Mahendra Chaudhary Zoological Park, Punjab (Misra et al. 2008),
Cytauxzoonosis	Captive	A Private breeding facility, Northern Florida, USA (Garner et al., 1996)
Eimeria (E. harmani & E. novowenyoni)	Captive	Nandankanan Zoological Park, Odisha (Patnaik and Acharjyo, 1971)
Isospora felis	Captive	Calcutta Zoological Garden, West Bengal (Chaudhuri and Choudhary, 1982); Lucknow Zoo, Uttar Pradesh (Agrawal et al. 1981), Mysore Zoo, Karnataka (Muraleedharan & Iswariah 1984); Mahendra Chaudhary Zoological Park, Punjab (Singh et al. 2006), Nandankanan Zoological Park, Odisha (Mahali et al. 2010)
Sarcocystis spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Trypanosomiasis	Captive	National Circus, Andhra Pradesh (Rao et al. 1995), Nandankanan Zoological Park, Odisha (Parija & Bhattacharya 2001); Calcutta Zoological Garden, West Bengal (Sinha et al., 1971, Sen Gupta, 1974); Himalayan Zoological Park, Darjeeling (Dasgupta et al., 1972); Hydrabad Zoological Park, Andhra Pradesh (Choudhary et al., 1986); Zoological Garden, Lucknow zoo, Uttar Pradesh (Arora, 2003d); Zoological Garden, Trichur (Nair et al., 1967); Sri Chamarajendra Zoological Garden, Mysore (Seshadri et al., 1983, Ziauddin et al., 1992); Nagpur Zoo (Upadhye and Dhoot, 2000)
Toxoplasma gondii	Free ranging	Russian Far East (Goodrich et al., 2012)

Gastro-intestinal parasites	Origin	Location
		Cestodes / metacestodes
Pseudophyllidea spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Taenia spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Taenia hydatigena	Free ranging	Sundarban Tiger Reserve (Bhattacharya et al., 2012)
Taenia taeniformis	Captive	Sri Chamarajendra Zoological Garden, Mysore (Dharnesh et al., 2016a)
		Trematode
Dicrocoeliidae spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Hymenolepididae spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Paragonimus spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)

Gastro-intestinal parasites	Origin	Location
		Cestodes / metacestodes
Paragonimus westermanni	Free ranging	Tarai area, Uttarakhand (Singh and Somvanshi, 1978); Rajiv Gandhi National Park, Nagarahole (Dharanesh et al., 2016b)
	Captive	Zoological Garden of Hamburg, Germany and Zoological Museum Amsterdam, Netherlands (Shipley, 1905);
Platynosomum fastosum	Free ranging	Russian Far East (González et al., 2007)
		Nematode
Ancylostomatidae sp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994); Russian Far East (González et al., 2007)
	Captivity	Sri Chamarajendra Zoological Garden, Mysore (Dharnesh et al., 2016a); Mahendra Chaudhary Zoological Park, Punjab (Singh et al. 2006)
Ancylostoma braziliense		Arignar Anna Zoological Park, Tamil Nadu (Thilakan et al. 2007)
Aelurostrongylus sp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Bronchostrongylus Subcrenatus	Captive	Assam State Zoo cum Botanical Garden, Assam (Nashiruddullah & Chakraborty 2001)
Capillaria spp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Capillaria aerophila	Captive	Assam State Zoo cum Botanical Garden, Assam (Nashiruddullah & Chakraborty 2001)
Dirofilaria immitis	Captive	Nandankanan Zoological Park, Odisha (Rao & Acharjyo 1993), Bhagawan Birsa Biological Park, Jharkhand (Gupta et al. 1999); Knoxville Zoological Park, USA (Kennedy and Patton, 1981); North Carolina, USA (Atkins et al., 2005).
Galonchus perniciosus	Captive	Nandankanan Zoological Park, Odisha (Acharjyo, 2004). Assam State Zoo cum Botanical Garden, Assam (Nashiruddullah & Chakraborty 2001); Thiruvananthapuram Zoo (Alexander et al., 2011).
	Free ranging	Nilgiri North Forest Division, Tamil Nadu (Kalaivanan et al., 2015)
Gnathostoma Spinigerum	Captive	Assam State Zoo cum Botanical Garden, Assam (Nashiruddullah & Chakraborty 2001), Arignar Anna Zoological Park, Tamil Nadu (Thilakan et al. 2007)
	Free ranging	Pench Tiger Reserve, Madhya Pradesh (Shrivastava et al. 2011)
Molineus sp.	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Mammomonogamus	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Ollulanus tricuspis	Free ranging	Sundarbans forest, West Bengal (Mandal & Chaudhury 1985)
Physaloptera sp	Captive	Nandankanan Zoological Park, Odisha (Mahali et al. 2010)

Gastro-intestinal parasites	Origin	Location
Cestodes / metacestodes		
Spirocerca lupi	Captive	Maharajbagh zoo, Maharashtra (Dhoot et al. 2002)
Spiruroidea	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Strongyloides spp	Free ranging	Russian Far East (González et al., 2007)
	Captive	Thiruvananthapuram Zoo, Kerala (Varadharajan & Pythal 1999), Pistoia Giardino Zoologico, Italy (Fagiolini et al., 2010)
Toxocara spp.	Captive	Nandankanan Zoological Park, Odisha (Patnaik & Acharjyo 1971), Thiruvananthapuram Zoo (Varadharajan & Pythal 1999), Pradhyuman Zoological Park, Gujarat (Parsani et al. 2001), , Nandankaran Zoo (Mahali et al. 2010), Assam State Zoo cum Botanical Garden, Assam (Nashiruddullah & Chakraborty 2001), Mahendra Chaudhary Zoological Park, Punjab (Singh et al. 2006), Fasano Zoo Safari, Italy (Fagiolini et al., 2010)
	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Toxocara cati	Free ranging	Russian Far East (González et al., 2007), Sundarban Tiger Reserve (Bhattacharya et al., 2012)
Toxascaris	Free ranging	Huai Kha Wildlife Sanctuary, Thailand (Patton and Rabinowitz, 1994)
Toxascaris leonine	Captive	Nawab Wazid Ali Shah Prani Udyan, Uttar Pradesh and National zoological Park, New Delhi (Chauhan et al. 1973), Nawab Wazid Ali Shah Prani Udyan and Allen Forest Zoo, Uttar Pradesh (Gaur et al. 1980; Arora & Das 1988), Maharajbagh Zoo, Maharashtra (Dhoot et al. 2002), Mahendra Chaudhary Zoological Park, Punjab (Singh et al. 2006), Nandankanan (Mahali et al. 2010), Assam State Zoo (Nashiruddullah & Chakraborty 2001)
	Free ranging	Russian Far East (González et al., 2007)
Trichuris sp.	Free ranging	Corbett National Park, Uttarakhand (Arora & Das 1988)

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Advisories issued by NTCA regarding tiger mortality reporting process

Sn. No.	Date	Advisory	Issuing authority
1.	21st July, 2007	Record of post-mortem examination No.1-9/93-PT	NTCA
2.	22nd April, 2009	Post-mortem protocol for ensuring transparency in cases relating to tiger mortality No. PS-MS (NTCA)/2009-Misces.	NTCA
3.	25th May, 2009	Post-mortem protocol for ensuring transparency in cases relating to tiger mortality and handling of injured / sick Schedule-I wild animals like tiger.(Ref: Endorsement of even number dated 22nd and 28th April, 2009.)	NTCA
4.	15th July, 2010	Record of Post-mortem examination No.1-9 / 93-PT	NTCA
5.	21st May, 2012	Reporting tiger deaths No 15-17/2011/NTCA	NTCA
6	17th December, 2012	Standard operating procedures for dealing with tiger death	NTCA
7	18th March, 2013	Standard operating procedure (SOP) for disposing Tiger/ leopard carcass/ body parts – reg No. 15-37/2012-NTCA	NTCA

Advisories issued by NTCA regarding infectious diseases

Sn. No.	Date	Advisory	Issuing authority
1.	22nd July, 2004	Preventive measures/surveillance for Trypanosomiasis in wild, free ranging conditions No.PS/Dir(PT)/2004-Misce.	NTCA
2.	29th November, 2005	Infectious Disease Alert No.PS-IGF(PT)/2005-MISCE.	NTCA
3.	13th January, 2014	Threat to tigers from Canine distemper virus No.1- 5/93-PT	NTCA

Advisories on biological sample collection and submission

Sn. No.	Date	Advisory	Issuing authority
1.	13th April, 2005	Note on the DNA typing facility No.PS-DIR(PT)/2005-MISCE.	NTCA
2.	23rd July, 2008	Use of Firearms in Poaching Mega Fauna No: 10-27/WCCB/2008/223	WCCB
3.	21st May, 2012	Reporting Tiger deaths No 15-17/2011/NTCA	NTCA

Miscellaneous advisories

Sn. No.	Date	Advisory	Issuing authority
1.	9th August, 2012	Stop monetary valuation of wildlife articles No.10-27/WCCB/2012/3874	WCCB
2.	30th January, 2013	Standard operating procedure to deal with emergency arising due to straying of tigers in human dominated landscapes No. 15-37/2012-NTCA	NTCA
3.	30th March, 2013	Advisory on investigation of the proceeds of wildlife crimes under PMLA No.10-27/WCCB/2014/Part-I/No.1 - 15/321	WCCB
4.	4th July, 2013	Capacity building in wildlife crime enforcement and investigation of wildlife offences No.10-27/WCCB/2012/814	WCCB
5.	14th November, 2014	Advisory on establishment of wildlife crime control units in States/UTs No.10-27/WCCB/2014/Part-I/No.1 - 14/1801	WCCB
6.	3rd March, 2015	Standard operating procedure to deal with orphaned/abandoned tiger cubs and old / injured tigers in the wild	NTCA
7.	3rd March, 2015	Standard operating procedure for active management towards rehabilitation of tigers from source areas at the landscape level	NTCA
8	12th June, 2015	Advisory on intimation of wildlife offences detected, specimens/articles seized and person detained to Wildlife Crime Control Bureau (WCCB) and State Chief Wildlife Wardens No.10-27/WCCB/2014/Part-I/No.2/15-741	WCCB

F. No. 15-1(32)/2015-NTCA
Government of India
Ministry of Environment, Forest and Climate Change
National Tiger Conservation Authority
*****

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Dated: 17.09.2015

To

The Director,
Wildlife Institute of India (WII),
Post Box No. 18, Chandrabani,
Dehradun – 248001.

Sub: **Request for permission to initiate study on "Patterns of mortality in free ranging tigers" – reg.**

Ref: 1. Your letter No. WHM/Vet/355/Proposal-NTCA dated 04.09.2015.
2. NTCA Technical Committee held on 07.09.2015.

Sir,

Reference is invited to the subject cited above. In this context, I am directed to inform you that the competent authority has approved the study as proposed, as part of the ongoing NTCA funded project "Strengthening Veterinary Implementations in Tiger Reserves" without any additional funding.

Yours faithfully,

(Dr. Vaibhav C. Mathur)
Assistant Inspector General (NTCA)

Copy to: WII File No. 15-40/2011-NTCA (For record).

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