Mangrove Tiger

An Ethological Study

By

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This book is dedicated to:

My late parents Shaktipada and Anima
My late wife Krishna
My daughter Runa
My son Sumanta
My son-in-law Saptarshi
and
My daughter-in-law Sagarika

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Preface

The tiger makes no secret of its danger, prowling around in a yellow and black stripy catsuit, a trend it shares with other perilous beasts. After all, most people never get to see them in the wild anyway, and for those who want to, we have ample footage and photographs of them in their natural habitat. In the new "human age", we are going to have to prioritise conservation efforts towards the species we do want to save. Habitat conservation is a key to preventing the animals' extinction in the wild. Perhaps the biggest problem with conserving the tigers' habitats is that these cats typically inhabit the crowded regions of the world. Ultimately, the reason for conserving tigers may be less to do with their ecosystem or tourist economy benefits, but simply because they are magnificent creatures. We have a moral and ethical imperative to save them in the wild.

I remember the story of Jim Corbett as a boy creeping up to a plum bush (*Zizyphus mauritiana*) with a tiger on the other side looking at him with an expression which said as clearly as words, "Hello, kid, what the hell are you doing here?", and, receiving no answer, turning around and walking away very slowly without once looking back. Such instances have earned the tiger the sobriquet "large-hearted gentleman".

In the wild its motions remain still, then its tiptoes forward. Its smell - an incredibly strong musky odour, mixed with the scent of meat - spreads with the slightest movement of the air to attack the prey. Afterwards, the unmistakable sound of bones of the prey being crunched by a hefty jaw is often heard. Hours pass away. With a massive bound, the enormous flame-coloured beast leaps away, disappearing deep inside the forest. It is still warm where he had been lying, with fresh blood and chewed up deer bones. It takes a while for my heart to return to its usual pace, but it takes longer for the grin to fade. That heart-thudding glimpse of copper fur "burning bright" will stain my memory forever; it will be truly devastating if mine is the last generation to have this experience.

Being the largest living cat species in the world, the tiger (*Panthera tigris* Linnaeus, 1758), essentially a crepuscular and nocturnal animal, is a highly adaptable carnivorous species, exhibiting tolerance to a wide range of

forest types, climatic regimes, altered landscapes and prey bases, particularly in the one and only mangrove habitat, inasmuch as there is no other tigerland like the Sundarbans left on earth. Over the last three decades, expansion of core area (by 28%) in the Indian Sundarbans and notification of a part of the buffer area as an additional wildlife sanctuary (WLS) i.e. West Sundarban in 2013, a vast tract of rich mangrove forests harbouring tigers, shrinking of the area available for fishing from 892.38 km^2 to c.523 km^2 are the positive initiatives by the forest department (FD) for ensuring a viable tiger population being dispersed in all the suitable habitats in the core, buffer or transboundary areas.

Contrary to what the name 'Sundarban' literally implies, i.e. 'beautiful forest', as the novelist Amitav Ghosh writes in his book 'The Hungry Tide', "There is no prettiness here to invite the stranger in." This archipelago is neither just a beautiful forest nor is it just home to the Sundari (*Heritiera fomes*) trees. It comprises an ecosystem that forms the frontal Gangetic belt. Over and above the utilitarian (narrow, broad and ethical) aspects of unique mangrove forests and rich biodiversity, particularly the most powerful bulwark against natural catastrophes, Sundarbans is the world's best attraction as home of the (Royal) Bengal tiger.

The Sundarbans is "a single ecosystem divided between the two countries" (Government of India and Government of Bangladesh) and "the Sundarbans ecosystem is greatly influenced by human use." We have to look after this iconic ecosystem if we want amazing animals like the Bengal tiger to have a chance of survival. The more of the Sundarbans that are conserved- via new PAs and reducing illegal poaching- the more resilient it will be to future climatic extremes and rising sea levels.

It is well-established now that tigers evolved in China, and two-million-year-old fossil remains were found in Central Asia, eastern and northern China, Siberia, Japan, Sumatra and Java—not very different from the modern range of the tiger. The continuous unbroken tiger habitat then with low human population and an abundance of prey enabled the tiger to occupy a wide range of landscapes in the areas around the Caspian Sea (Caspian tiger, *Panthera tigris virgata*), Siberia and northern China (Siberian tiger, *P.t. altaica*), central and southern China (South China tiger, *P.t. amoyensis*), the Indian subcontinent (Indian tiger, *P.t. tigris*), mainland

Southeast Asia (Indo-Chinese tiger, *P.t. corbetti*), the island of Bali (Bali tiger, *P.t. balica*), the island of Java (Javan tiger, *P.t. sondaica*), and the island of Sumatra (Sumatran tiger, *P.t. sumatrae*).

All the subspecies are distinguishable on the basis of the differences in the colour and striping of their coats and the skulls. The three island subspecies were once connected with the mainland species when the climatic conditions were much colder and there were ice bridges.

Taxonomically, the Sundarbans mangrove tiger is the "nominotypical subspecies" (*tigris*) known as the Bengal tigers since Bengal (without specific location) is traditionally fixed as the typical locality for the binomial *Panthera tigris*, commonly known as the continental tiger. The British taxonomist Pocock subordinated the Bengal tiger under the trinomial nomenclature *Panthera tigris tigris* in 1929, a native to the Indian subcontinent (Kitchener *et al*., 2017) and most numerous of all subspecies.

At the end of the last glaciation (c. 115,000 – c. 11,700 years ago), the climate warmed, the sea level rose and the islands became isolated. This isolation led to the evolution of small-sized tigers—island tigers that are half the size of mainland tigers. Today, this phenomenon is also seen in the Sundarbans tigers, which has remained isolated from the mainland tiger habitat for about 500 to 1,000 years ago. Perhaps the small size of Sundarbans tigers is an adaptation in the marshy mangrove habitat for such longer period.

"The presence of a tiger", writes Romila Thapar 'In Times Past', "represented an affiliation with the most powerful and positive force for good in the natural world. Local people believed the tiger was the intermediary between heaven and earth. Tigers have played integral roles in ancient and modern cultures and folklore, being used to represent various characteristics and symbolisms throughout the centuries."

The most ancient records of tigers are found in the cave paintings of central India dated between 100,000 and 30,000 BP (Badam and Sathe, 1991). There are references to the occult powers of tigers in the Atharva Veda, Ramayana and Mahabharata (circa 400 BCE to CE 400). We find the ecological role of tigers in Nature in the Mahabharata.

"If there is no forest, then the tiger gets killed; if there is no tiger, then the forest gets destroyed. Hence, the tiger protects the forest and the forest guards the tiger!"

- Mahābhārata (Kumbhaghonam Edition) - Udyoga Parva: 5.29.57

The Bengal tiger, a 'living heritage', is often familiar as the 'Royal' beast in all its natural glory- an important symbol in the construction of British imperial and masculine identities during the 19th century (Sramek, 2006). E.P. Gee thinks the Royal may have originated from the fact that a tiger was shot by the Duke of Windsor when he was the Prince of Wales. Hence, by virtue of being recognised as 'king of the jungle' with a gruesome reputation, the tiger was sculpted on seals of Indus Valley civilisation of Harappa and Mohenjo-daro (2,500 to 1,700 BC) and later became the symbol of the Chola Empire (300-1279 CE).

Designated as the national symbol (India and Bangladesh) in early 1970s and subsequently as a World Heritage Site, Sundarbans has a dignity to be preserved. Arin Ghosh (1999), the then Chief Wildlife Warden, West Bengal, writes:

> The 'Royal Bengal Tiger', as it is emphatically called in this part of the country, is the pride of Bengal. It has been intricately enmeshed in the psyche and profile in anything Bengali; be it fiction or folklore, its religious beliefs or its serious literary pursuits.

The popular literature of the Sundarban delta presents an intellectual history of religious and cultural encounters in the region, which transformed humans' relationship with nature by forging the ethics and morality of forest resource use between humans and non-humans.

The mangrove forest is a challenge even for the Bengal tiger- with floods, marshy banks, shifting tides, and pneumatophores of mangrove roots that stick out of the ground like spikes (Mallick, 2021). Most importantly, the 'Mangrove tiger', often represented as ruler of the mangrove forests, exhibits certain distinctive morphological adaptations that make them particularly suited to the mangrove habitat. Their striped coats help them blend in well with the sunlight filtering through the treetops to the forest floor. The big cat's seamless camouflage to their surroundings is enhanced

because the striping also helps break up their body-shape, making them difficult to be detected by the unsuspecting prey.

Life in the lush mangrove forests can be both beautiful and savage; a paradise on the one hand, when viewed by us from a safe distance, providing camouflage to a daily hell of trials and survival for those wild animals who live there, the subordinates and preys as well as the top ambush predator. The powerful tiger is by nature born leader, dynamic, very confident, perhaps too confident sometimes, noble and fearless, respected for courage, even by those timber mafias and poachers other than the common people. Tigers are unpredictable, always tense and addicted to excitement. They love adventures when hunting the grazing primary consumers and defending their own territory from other would-be killer machines, like being obeyed and not tolerating others to compete with and challenge them. The tiger usually chooses to operate alone in the natural kingdom, a dictator in peak physical age (optimal condition), who dominates over other associates in intra- and inter-specific interactions. Because of this, they play a crucial role in maintaining a healthy habitat.

I had visited the Sundarbans innumerable times since the mid-1970s observing the mangrove tigerland as well as the northern Bengal mainland intensely. During the last two decades, many of my write ups, highlighting the Bengal tigers in their isolated mainland and island habitats with special emphasis to their behavioural ecology and the most effective ways to protect them, have been published in different journals. Here are some of my published articles and academic books with special emphasis on *P.t. tigris* (Mallick, 2002; 2010a, b; 2011; 2012; 2013; 2015; 2019a; 2023; Bahuguna and Mallick, 2010). With the strong belief that saving tigers offers the best bet for recovering the storehouse of the natural gene pool to address future climatic challenges, I have written the book entitled 'Mangrove Tiger' with compassion, clarity and concern. It is a vivid narration on the biological structures and naturalistic behaviour of the subspecies, its critical role in shaping natural ecosystems, and their striking presence in our collective imagination. In spite of our joy and sensation of being present in the mangrove tigerland, the predicted perils thereof are haunting us like nightmares, but we are 'cautious optimists' professing and working for balancing human emancipation and nature conservation, which is critical

for making more room for the mangrove tigers. Conservation is a never-ending war that has to be dealt with absolute passion.

Personally, I have had a special affinity with or passion for the Bengal tiger (*Panthera tigris tigris*) ever since I was a young student studying in the Calcutta university. During the early 1970s, I had my first close contact with a captive young Bengal tiger named 'Shankar', a healthy male performer in the Great Oriental Circus, and got stunning images of him while I was working temporarily as a musician on the stage in that circus and had the opportunity to observe his gait inside the ring and within the campus, and *inter alia* jumping through the rings of fire even though tigers are instinctively afraid of fire (a cruel practice indeed banned in 1998). Although I believe that despite the appearance of pseudo-domestication in some trained tigers, the tigers retain their predatory instincts and neural-visceral reflexes, and they can inflict serious wounds using their teeth or claws suddenly and without forewarning, my beloved Shankar was not of that type, rather calm and quiet, a majestic individual. There were no such untoward incidents. However, I used to note down every minute details about Shankar. He was a good actor too! He was the main attraction of a Bengali comedy film named "Once there was a tiger (*Ek je chhilo bagh*)" released in 1973. The shooting used to start after the night show and I was always present at the shooting spot as an inquisitive spectator in order to be familiar with his nocturnal attitudes and behaviour. At midnight, Shankar entered a hut-like structure by climbing on the thatched roof and dropped on the floor by making a hole. Ultimately, he returned to the wild without injuring anybody. After a few months, I left the circus when it shifted to another state and carried on with my academics.

I always wanted to create a new document about the world-famous king in the wild- the Bengal tiger in the greater Sundarbans mangroves, a mangrove swamps on the tropical coasts of India and Bangladesh, locally known as *bãdãbãn* or *bãdã*. Very soon my dream was fulfilled. After completing my post-graduation and passing the competitive examination incredibly, I joined the Wildlife Wing Headquarters in West Bengal, a state in the eastern India bordering Bangladesh and, naturally, got the legal right to visit the tigerland every weekend (Saturday being half-holiday then and Sunday a holiday) to lark around the horizontal and vertical landscape to my heart's content, all the way down to the Bay of Bengal via the Haldibari

Camp under National Park (NP) (West) Range because during late 1970s and the 1980s, Haldibari and Mechua were good sites for tiger sighting, although during the early 21st century I enjoyed the ambience of the Burirdabri camp under Basirhat Range on the international border with the Bangladesh Sundarbans, and got the opportunity of sighting an incident of deer-hunting by a resident tiger at night.

Having seen a tiger in the wild is an incredible privilege, which not many people in the world can boast about. And for many of us, the first sighting of a wild tiger is probably the most remarkable one. But sighting a tiger in the mainland cannot be compared with the charm of locating a half invisible tiger, a semi-aquatic feline, soaked in water and coated in mud, just landed after crossing a river. The diffused light makes the evergreen mangrove swamps mysterious, where the trees are short, have a dense canopy, grow very close to each other and hence visibility is poor compared to the mainland. The best bet to see the tiger in the Sundarbans is to sail through the water courses, expecting the tiger to emerge from the forests on the shore, as I did while approaching the Haldibari jetty in the morning. The chances of sighting a big cat through the pattern of light and shade are usually very remote. I was fortunate to have a glimpse of the healthy, vibrant and glowing orange fur and black stripes, the graceful paws, terrifying eyes but it was not directly looking at me; the wild eye leapt across the bush before bounding away. That's my first encounter with the largest feline in the wild.

I knew Dr. Kalyan Chakraborty, the then Field Director, Sundarban Tiger Reserve (FD, STR), used to spend night after night sitting in the wooden watchtower at Haldibari with the facility of a 360 degree view, overlooking a sweetwater pond with frontal, left and right strip of land bereft of any vegetation for such a precious sighting of the prey and predator from a distance. My first tiger sighting took place onboard while approaching the jetty of Haldibari camp. Since then, I have had so many rewarding opportunities to encounter this majestic big cat in the mangroves. It was so special, most memorable, unpredictable, breathtaking and vibrant to me from an ethological perspective. Their presence can be felt by the prey animals, even when you can't see or smell them; you can rest assured about their presence or footprints in the mud of every nook and cranny of their habitat and they can sense your presence because they are silently

monitoring your every movement in the world's most mysterious tigerland.

In spite of the fact that the mangrove forest is a challenging habitat with storms, floods, marshy banks, shifting tides, and pneumatophores that stick out of the muddy ground like spikes at a height of 20-30 cm above soil to make hunting very difficult (20% success-rate), the single-patch mangrove forests is the only area in the world known to have the Bengal tiger, an endangered charismatic megafauna, drawing global public attention and conservation efforts. Whereas for the captive tigers, physical wellbeing is enough for their survival, for a wild Sundarbans tiger physical and psychological performances together can only ensure its survival.

Systematic ethological research on the Bengal tiger in the wild, particularly when the habitat is inaccessible mangroves, is a very challenging task. Such research works were initiated as a sequel to the institutional tiger conservation efforts during the early 1970's. At present a variety of topics such as foraging and feeding behaviour, habitat selection, social and reproductive behaviour, chronobiology, chemical communication signals and neurobehaviour are being investigated by the ethologists. These analyses revealed that there has been a gradual increase in the availability of books and scientific journals in the field of tiger behaviour. The number of workers has increased and the fields of investigation in the area of ethology have diversified. An analysis of the development of tiger ethology in the Indian subcontinent indicates that the progress of this discipline as a major field of research and teaching during the 21st century is satisfactory. Further, more emphasis should be given to field oriented investigations aiming at conservation of the tiger along with coexistence and sustainable development as tiger population is close to saturation. If the present trend is maintained, ethology should develop as a major discipline of tiger research in future. In this perspective, ethological research on endangered Mangrove tigers has a great prospect at local, regional, national and global levels. Tiger conservation can support the realisation of UN Sustainable Development Goals in Asia.

Continuous observations and recordings of individual and social behaviours of big cats in the Sundarbans mangroves, biological rhythms, assessment of their daily activities, life cycle in different seasons, ecological

adaptations and development using ethological and physiological parameters, and management of their habitats appears to be particularly complex inasmuch as these animals are indeed prone to develop species-specific stress-related behavioural problems: the females usually show stereotypical behaviour whereas the males do not.

This book contains well-researched (literature review/field surveys) and 48 years' experience-oriented information on the origin and adaptation of Bengal tiger (*Panthera tigris tigris*), the only large carnivore species inhabiting the mangrove forests across the world. A published book highlighting the updated information on the migratory behaviour, plant-tiger interaction, morphological and behavioural adaptations of the Bengal tiger in the mangrove ecosystem is not readily available. In this context, this book is a different one. This monograph is ideal for the researchers, postgraduate and graduate students in zoology, botany, ecology and conservation. This comprehensive treatise will serve the professionals, such as foresters, environmentalists, conservationists, resource managers, planners, government agencies, academic institutions, NGOs and naturalists.

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I would like to register my acknowledgement of and sincerest appreciation to all the individuals, institutions including the Wildlife Wing of the Forest Directorate, Government of West Bengal, for an intriguing work opportunity for 37 years from 1976 to 2012, quite literally a treasure trove, the giant one, to the best of my knowledge and belief. The Wing was created after promulgation of the Wildlife (Protection) Act, 1972 in 1973. Since then, the Wing has not only contributed to the conservation of tigers in the Sundarbans but also the conservation of the entire ecosystem.

As a part of the wildlife management system, I had learnt the intricacies of tiger conservation since the initial stage, particularly from Late Dr. Ram Krishna Lahiri and Late Amal Bhusan Chaudhuri. From 1999, I was preparing a handbook on the mammals of South Asia, which was published in 2010 (see reference), when I had learnt a lot about the tigers. I am also indebted to Mr. Ganesh Behari Thapliyal, who engaged me in the in-house research projects for biodiversity assessment of the protected areas (PAs) in the state and entrusted me to establish a wildlife data bank, which helped me immensely in writing this book.

After retirement from the Wildlife Wing, I was involved in a Sundarban-based project for five years, which was published in 2020 by the Cambridge University Press, UK, entitled 'Primates in flooded habitats: Ecology and conservation'. During all these years, I have had a thorough experience of working in the Sundarbans mangroves in India and Bangladesh, which has enriched my knowledge about the tigerland and its wild habitants and I could include those data in this book. Special thanks go to three editors-Katarzyna Nowak, University of the Free State, South Africa, Adrian A. Barnett, National Institute for Amazonian Research, Brazil, and Ikki Matsuda, Chubu University Academy of Emerging Sciences, Japan for involving me in this novel project.

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I always remember the crew of MS Manorama, who miraculously saved my life from drowning in the Bay of Bengal due to a sudden storm surge in the evening (a nor'wester) during the return trip from Haldibari camp.

There are countless official colleagues, friends and associates to whom I would like to convey my gratitude for their help throughout the preparatory phase, but for the sake of brevity here I could not mention their names. I deeply regret this.

Finally, salute to everyone on my publishing team of the Ethics International Press Limited for their unstinting support.

Chapter 1
Introduction

"A tiger does not shout its tigritude, it acts."– Wole Soyinka

Tiger Evolution

Through palaeo-genomic analyses, Hu *et al.* (2022) identified a Pleistocene tiger from northeastern China, dated to beyond the limits of radiocarbon dating (greater than 43,500 years ago). Based on the mitochondrial genome, the divergence time of this ancient lineage was estimated to be approximately 268 ka (95% CI: 187-353 ka), doubling the known age of tigers' maternal ancestor to around 125 ka (95% CI: 88-168 ka). One of the Bengal Tiger's oldest ancestors is the sabre-toothed tiger (*Smilodon populator* Lund, 1842) that lived 35 million years ago in South America and *Proailurus lemanensis* (Filhol, 1879), a smaller prehistoric cat, living 25 million years ago in Europe and Asia. Other old tiger fossils date back to 2.16-2.55 million years in China. Scientists believe that a big change was occurring at that time when the tigers had to migrate very far to survive. Some think that it was a rise in sea level, then South China would have been flooded and that is where the first tigers were.

The Bengal tigers are thought to have come into India around 12,000 years ago because no tiger fossils have been found in the area before that time. The Bengal tiger has eventually adapted to its new habitat conditions. The biogeography of the Bengal tiger is presently confined to India as well as parts of Bangladesh, Nepal, Bhutan, southwestern China, Medog, Tibet autonomous region, and Myanmar.

The tigers are present across 11 Asian nations, despite their recent range collapse, occupying diverse habitats including estuarine mangrove forests (the Sundarbans), dry deciduous forests (parts of India), tropical rainforests (Malay Peninsula), and cold, temperate forests (Russian Far East)(Armstrong *et al.,* 2021). Demographic models suggest recent divergence (within the last 20,000 years) between subspecies and strong

population bottlenecks (*ibid*) like natural or man-made disasters, geographic isolation, and natural selection. Amur tiger genomes revealed the strongest signals of selection related to metabolic adaptation to cold, whereas Sumatran tigers show evidence of weak selection for genes involved in body size regulation. However, the specific adaptations of the various populations to their habitats remain largely unknown like the tigers occupying the estuarine mangrove forests (the Sundarbans). However, their sampling of the most populous (Jhala *et al*. 2015) and genetically diverse tiger subspecies- the Bengal tiger- was limited across habitats.

Taxonomy

At least six lines of correlated evidence are required for taxonomic certainty-

1. Morphological- Taxa are diagnosably distinct on the basis of several characters (e.g. skull, pelage) in comparison with all other members of a species or genus (excluding hybrids) from throughout their respective geographical ranges.
2. Genetic- Taxa are genetically distinct based on a variety of genetic information, including mtDNA, Y-chromosome markers, Single Nucleotide Polymorphisms SNPs, etc.
3. Biogeographical- Distinct taxa are more likely to be recognised where there are distinct geographical barriers relevant to the taxon, e.g. rivers, seas, mountains, deserts, or where geological events, such as sea-level changes, or volcanic eruptions are broadly coincident with coalescence times, or where recolonisations following climate change are consistent with former refugia.
4. Behavioural- e.g. predisposition to taming.
5. Ecological- e.g. use of distinct habitats with appropriate adaptations.
6. Reproductive- e.g. seasonality or not of reproductive cycles.

Scientific name

The tigers, having binomial (generic and specific) scientific nomenclature *Panthera tigris* (Linn. 1758), with their distinct yellow to orange-red coat,

white areas on the chest, neck, and inside of the legs, individually (not uniform) identified by unique face-markings, broken black-stripes and tail-rings as well as pugmarks, are one of the most captivating carnivorous species on our planet and have evolved to thrive in the diverse climates and ecosystems, which have allowed them to become one of the most successful big cats on the planet. Historically, they inhabited much of Asia, and various tiger subspecies with somewhat different characteristics, naturally migrated, and spread out over time, for which a third (trinomial) name 'tigris' is applied.

The present system of classification of the species is a development from that originally proposed by an eighteenth century biologist Carl Linnaeus. The taxonomic classification of the big cats has fluctuated since new morphological and genetic research has been documented. The Felidae (Fischer von Waldheim, 1817), originated in Central Asia in the Late Miocene, has 18 genera encompassing about 40 species. There are 13 genera within the Felinae subfamily, four genera within the Pantherinae subfamily and one within the Acinonychinae subfamily (Pocock, 1917). Initially, Linneaeus classified it as *Felis tigris* (now Basionym of *Panthera tigris*), but later scientists placed it under the genus *Panthera* because of its distinctive elastic hyoid bone, a U-shaped structure situated at the root of the tongue in the front of the neck and between the lower jaw and the largest cartilage of the larynx or voice box.

Felid Evolution

The modern felids of the 'Panthera' lineage diverged from the ancestral cat species around 10.8 million years (Myr) ago, while five large ('Great Roaring Cats' of genus *Panthera* Oken, 1816) and two medium (Clouded leopards of genus *Neofelis* Gray, 1867) felids diverged between 6 and 6.4 Myr ago (Luo *et al.* 2010) and spread in various environments from high mountains, savannahs to the rainforests of Africa, Asia and Central and South America. The split of the *Panthera* lineage was followed by a rapid series of divergence and migration events starting around 3.7 Myr ago that led to the five extant *Panthera* species [Lion (*Panthera leo* Linnaeus, 1758), Jaguar (*Panthera onca* Linnaeus, 1758), Snow Leopard (*Panthera uncia* Schreber, 1775), Leopard (*Panthera pardus* Linnaeus, 1758) and Tiger (*Panthera tigris* Linnaeus, 1758)]. The Asian-derived *Panthera* species

subsequently spread into America (Jaguar), Africa (Lion and Leopard) and others remained in Asia (Tiger, Snow Leopard and Clouded Leopard). Paleo-tigers are ancestral forms of the phyletic line that only much later led to the current tiger. The most recent common ancestor lived about 110,000 years ago (Liu *et al.* 2018). They were compelled to spread southwards in search of suitable habitats as successive Pleistocene glacial and other geological events made Northern Asia inhospitable.

Prior to three extinctions [Balinese tigers (*Panthera tigris balica*) since the 1950s, Caspian tigers (*P.t. virgata*) since the mid-1900s, and Javan tigers (*P.t. sondaica*) since the mid-1970s], there were eight different tiger subspecies. There is, however, some debate today that the five remaining subspecies should, in fact, only be three (based on DNA analysis two merged with *P.t. tigris*)- (a) Type locality Bengal, fixed by Thomas, 1911, *Proc. Zool. Soc. Lond*., 1911: 135 [now coupled with the South Chinese and Corbetts (with three common names- (i) Corbetts named after Jim Corbett, famed hunter of man-eaters and conservationist, (ii) Indochinese and (iii) Malayan tigers], (b) Amur (erstwhile Siberian) and (c) Sumatran.

The tiger population of the Sundarbans is paraphyletic (i.e. descended from a common evolutionary ancestor but not including all the descendants) within the Bengal tiger (Aziz *et al.,* 2022). The tigers inhabiting the Sundarbans mangrove forests were assumed to be migrants from the mainland especially Central India, via Chhota Nagpur Plateau and have been isolated recently; but phylogenetic ancestry of the present residents has remained poorly understood until recently. When an established tiger habitat reaches its full carrying capacity of breeding population, generally the young tigers are forced to move out in search of new territories risking their lives while passing through hostile terrains. They are known not only to move over long distances between fragmented forests through corridors to establish their own territories but also able to reproduce in new areas, thereby contributing to the genetic diversity of subpopulations. Such dispersal and subsequent reproduction is crucial for the maintenance of long-term genetic health in the fragmented tiger population in the Sundarbans mangroves.

Studies suggest that the Bengal tiger crossed the Eastern Himalayas through the corridors of North-east India, and occupied most of the

country since the Late Pleistocene between 12,000 and 16,500 years ago. While tigers populated Central India about 10,000 years ago, their population subdivision began only recently owing to habitat fragmentation, historical events, human pressure and land-use patterns. The regional tigers diverged and isolated from each other around 8,000-9,000 years ago due to intra-specific competition, loss of habitat and corridors.

About 6000 years ago (in the mid-Holocene), the shoreline of the North-eastern Indian Peninsula was situated to the west of the present shoreline which was comparatively closer to the foothills of the Eastern Himalayas. Therefore, the present Sundarbans area did not exist for terrestrial life until the shoreline had moved eastward and the excess population of tigers could arrive from Peninsular India. Hence, the gene pattern of the Sundarbans tiger is identical to the big cat population of the Central Indian landscape including the States like Madhya Pradesh, Chhattisgarh, parts of Andhra Pradesh and Maharashtra. In fact, they migrated to the new coastal mangrove habitat on the east, formed between 2500 and 5000 years ago by the silt deposition of the river Ganges and its tributaries/distributaries. Since the Sundarbans tiger is morphologically distinct in terms of skull and body size the population was evaluated further to determine if it is an evolutionary significant unit (Barlow 2009).

Distribution

Historically, tigers inhabited Mesopotamia and portions of South and East Asia. During the 19h century, they were also found in parts of Turkey, China, Afghanistan, Iran, and Russia. Their eastern distribution ranged from Korea, eastern China, and selected areas within the region of Southeast Asia.

The extant subspecies are native to a wide range of highly threatened habitats throughout Asia, including tropical forests, savannas, grasslands, mountainous regions and even mangroves. They are confined to 11 range countries including India and Bangladesh (study area). These habitats provide them with food, water and cover they need to survive and procreate.

The historical distribution of tigers exemplifies the variety of habitat types to which they have adapted. The tigers are found mainly in the forests of tropical Asia, although they historically occurred more widely in the drier and colder climes with a sufficient prey base, particularly native ungulates-odd-toed (Perissodactyla) and even-toed (Artiodactyla), key to their successful reproduction.

In Turkmenistan, Uzbekistan, and Tajikistan, the tiger was found in the drainage basins of rivers and lakes, where they hunted in the "tugai", which consists of thickets of low-stature trees (turanga, tamarisk), shrubs, and dense reed beds. In Kazakhstan, tigers sometimes ascended into montane forests, attaining heights of 2,500 m, in the summer in pursuit of wild boars. There are also records of tigers in the Himalayas at altitudes of almost 4,000 m, although in most areas these big cats remain well below 2,000 m. In China, they occupied grass thickets, montane sub-tropical evergreen forests, and mixed forests dominated by oak and poplars. Tigers in the Russian Far East live in low mountainous terrain dominated by nut pine, birch, oaks, fir, and spruce. Winter is harsh in this region with deep snow and temperatures dropping to -34°C. In Sumatra and Malaysia, tigers are found in lowland humid tropical rainforest, where precipitation exceeds 2,000 mm annually. In the outwash areas south of the Himalayas, tigers inhabit the "terai", a belt of floodplain habitat dominated by marshes, swamps, oxbow lakes, and tall, dense grasslands intermixed with riverine forest. Sal forest, a climax form of moist deciduous forest, occurs on the slopes of the adjacent hills.

In India, tigers inhabit the tropical, wet evergreen, and semi-evergreen forests of Assam, the mangrove swamps of West Bengal and neighbouring Bangladesh, the vast expanses of dry deciduous forest in the central plateau, the tropical moist and dry deciduous forests of the Western Ghats, and the thorn forests of Rajasthan and Gujarat (now extinct, the last reported tiger in Dangs was shot by a poacher near Waghai in 1983). In Ranthambore NP, Rajasthan, tigers also use the ancient temples and fortresses as places to live during the day. The tiger habitats range from the temperate pine-oak forests of the Russian Far East and the rocky mountain slopes of Manchuria to the tall grasslands of Nepal, up to the mangrove swamps of the Sundarbans and, of course, the rainforests of Malaysia and Indonesia in the Southeast Asia.

The extant tigers are discussed below at subspecific levels.

Mainland Asian populations

(1) The Bengal Tiger (*Panthera tigris tigris* Linnaeus, 1758) has reddish-orange coloured fur with broad black vertical stripes on its head and back, which are also found on the skin, so that if it were to be shaved, its distinctive coat-pattern would still be visible. It is the native of mainland Asia and confined to the Indian Subcontinent. At the beginning of the 20th century, the scientists believe that there were more than 100,000 tigers throughout most of Asia and about 40,000 tigers were estimated to inhabit the Indian subcontinent.

The Malayan tiger (*P.t. jacksoni*/*malayensis*), native to Peninsular Malaysia, and the northern Indo-Chinese Tiger (*P.t. corbetti*) in Cambodia, China, Laos, Eastern Myanmar, Thailand and Vietnam are now considered *P.t. tigris* subspecies (Kitchener *et al.* 2017); the gene flow between the Sundarbans mangrove islands and the mainland populations is highly restricted.

(2) The Amur (Siberian) Tiger (*P.t. altaica*) is lighter and has fewer stripes than other tiger subspecies. It has long and thick hair to help them stay warm in their cold climate of eastern Siberia, Manchuria to Northeast China, and possibly North Korea; 38-45 individuals remain in the mountain forests along the Sino–Russian border (Xiao *et al.* 2016);

(3) The south China (Amoy) Tiger (*P.t. amoyensis*), native to southern China, listed as Critically Endangered, has not been directly observed in the wild since the 1970s; during field studies (camera traps, GPS technology and extensive sign surveys) in 2001, no evidence of tigers or scats were found and is possibly extinct; and

Sunda island populations

(4) The Sumatran Tiger (*P.t. sumatrae* Pocock 1929), darker in colouration than other tiger species with a deep orange to reddish coat and black stripes, has a population of <400 individuals estimated in 2022; it occurs in tropical broadleaf evergreen forests, freshwater swamp forests and peat swamps.

Extinct tigers

Three subspecies of the tigers are now extinct:

(i) The Javan Tiger (*P.t. sondaica* Temminck, 1844), native to the Sunda islands and inhabited lowland tropical forest until the mid-1970s; last sighted in 1976 and, in 2003, listed as extinct (IUCN Red List) but many are hopeful that the Javan tiger still lives;

(ii) The Bali Tiger (*P.t. balica* Schwarz, 1912), native to the tropical forests of Bali island; extinct since 1950s; and

(iii) The Caspian (Turan/Hyrcanian) Tiger (*P.t. virgata* Illiger, 1815) inhabited Western and Central Asia in dry river valleys of the Taklamakan, western slopes of the Tianshan mountains, Amudarya and Syrdarya river valleys, shores of the Caspian sea, Elburz mountains, eastern Turkey, Tigris and Euphrates river valleys; assessed as extinct around the 1950's.

Population dispersal

The tiger's natal philopatry, which is defined as continued residence on the natal home-range past the age of independence from the parents, across various ecological and life-history regimes depends on a number of variables like adult turnover rates, habitat saturation, spatial patchiness of resources, advantages of familiarity with the natal home range, and reliance on extensive home range "improvements". The most interesting consequence of natal philopatry is the continued spatial association of kin into adulthood.

The recent history of the tigers in the Indian subcontinent is consistent with the lack of tiger fossils from India prior to the late Pleistocene and the absence of tigers from Sri Lanka which was separated from the subcontinent by rising sea levels in the early Holocene. The tigers expanded their range even in the drier regions of North-West India by moving into newly opened ecological niches. While Ranthambore in Rajasthan, cut off from other tiger conservation landscapes, is the western-most extant population of wild tigers, the Sundarbans landscape is the easternmost habitat of the Bengal tiger and completely isolated from its northern and south-western counterparts. Difference between the island tigers and mainland tigers is that mainland tigers with higher body mass and bigger

sizes are more equipped with catching larger prey while the island tigers are efficient for preying on the smaller ungulates (Seidensticker and McDougal, 1993).

Studies revealed fascinating levels of tolerance and adaptation in tigers as they inhabit and persist in human-dominated landscapes while dispersing in search of suitable habitat. Studies also showed that tigers can exist without being detected by people and go to extreme extent to avoid conflict in order to achieve safe passage over hundreds of kilometres. A wild tigress fitted with a satellite GPS collar was tracked as she dispersed in the Vidarbha region of the Central Indian Tiger Landscape. The tigress had been rescued by FD staff on 12th October 2011 from a water duct she had fallen into in the Nagpur district of Maharashtra and was released on 27th November 2011 in a forest near her site of capture.

It was observed that she remained in the same forest for almost a month until 25th December and then started moving eastwards into a human-dominated landscape. Human density in the district averages 409 people per km^2 and village density here averages 5.3 villages per km^2. In the immediate area of the tigress' vicinity, human density was still as high as 200 people per km^2. The landscape she now inhabited was a mix of forests, agricultural fields, villages, schools, roads etc. The home range of the tigress in such a challenging landscape encompassed a massive 431 km^2. She avoided human detection by being almost entirely nocturnal and resting in foliage and shade by day. The scientists tracking her found that she often rested very close to places where humans were active by day- sometimes as close as 100 metres- but no untoward incidents ever occurred. She was subsisting largely on a diet of wild pigs, though she also killed cattle and even scavenged.

The scientists lost track of her after her collar ran out of battery and stopped functioning, but she was photographed a year later in April 2013 just 40 km from her site of release, indicating that she was still inhabiting the same region.

The area is in the vicinity of the Tadoba-Andhari, Pench and Navegaon-Nagzira TRs, all of which are source sites from which tigers can potentially disperse into the rest of the landscape.

During the study, the tigress demonstrated the ability of her species to cross human habitation, agricultural fields, roads and railway lines in its search for safe habitat when moving from one PA to another. The case of this dispersing tigress outside PAs implies that conflict is imminent and that activities such as mining, construction of canals and deforestation cause fragmentation of forests and increase human-tiger conflict. Yet in areas where large carnivores are forced to use human-dominated landscapes to disperse, conflict remains minimal particularly if precautions and safeguards are taken by people.

Gour *et al.* (2013) established male-biassed dispersal and female philopatry on the basis of genetic data collected from 22 females and 6 males within the core area of Pench TR, Madhya Pradesh. Females showed positive correlation up to 7 km (which corresponds to an area of approximately 160 km). However this correlation is significantly positive only up to 4 km (corresponding to approximately 50 km). Males do not exhibit any significant correlation in any of the distance classes within the forest (up to 300 km). Evidence of female dispersal up to 26 km in this landscape was also observed.

The tiger's home ranges in the Sundarban mangroves are small in the suitable habitats for the breeding, feeding, resting, or sheltering. Here, the habitats have been changed or fragmented and natural resources are depleted due to overexploitation; for example, where the preferred large ungulate prey is scarce. In order to augment the mangrove habitat potential and facilitate the continued dispersal of tigers within the landscapes, priority ecological corridors have to be restored and connectivity maintained involving the multiple stakeholders.

For survival, the tigers need unrestricted and safe passage in its home range including the natural corridors to breed, hunt and establish their own territories. They live in diverse landscapes from rainforests to grasslands, savannahs, montane forests, boreal forests and mangrove forests. But, when the extensive tiger landscapes are historically cut into more isolated fragments resulting in loss of preys and corridors in between, either broken or lost forever, tigers are increasingly wedged in the smaller habitats that can lead not only to inbreeding, but also intraspecific competition and conflict for the scarce prey animals, breeding partners and other biological

needs, which is ultimately associated with inflicted injuries or even death. In addition, natural and anthropogenic threats also cause habitat destruction and reduction in viable breeding populations.

Aziz *et al.* (2018) assessed the genetic status of these populations to reveal the effects of dispersal barriers, "Microsatellite analyses exhibit a signature of fine-scale genetic structure, which might have been the consequence of limited tiger dispersal due to wide rivers across the Sundarbans. Similarly, mitochondrial data show a historic pattern of population isolation that might be due to wider rivers across the entire Sundarbans shared by Bangladesh and India. Given the intrinsic nature of the mangrove habitat embedded with numerous rivers, increased commercial traffic and human activities may further impede tiger dispersal across wide rivers, escalating further genetic isolation of the Sundarbans tigers."

Comparatively, dispersing tigers in the Vidarbha landscape are using a much wider swathe of the landscape outside PAs for movement than earlier known. It extends well beyond forested structural corridors. Tigers in this landscape were pushing the boundaries of humans to accept the risk of exploring a human-dominated landscape. Data has also shown extensive use of agricultural lands for movement. Tigers have used whatever small fragment of forest patch or parcel of cultivated land with standing crops, to seek refuge during daytime. The purview of tiger conservation, which till date was thought to be restricted to lands under the jurisdiction of the forest management, now seems to extend beyond such bound boundaries and into a realm where successful conservation effort should necessarily include many stakeholders. The local people, district administration, local NGOs, and various development agencies should work in tandem with forest management. The report provides clues to managers to target proactive and preemptive management interventions for conflict prevention, mitigation, and connectivity conservation.

Population status

While Bangladesh, Bhutan, Indonesia, Malaysia, Nepal, Russia and Thailand harbour several hundred tigers, only a few are found in Myanmar and China. Tigers are now extinct from Vietnam, Laos and Cambodia. The largest population of global wild tigers (Bengal tiger *Panthera tigris tigris*) is

found in the Indian subcontinent and is mostly restricted to the Central Indian landscape, whereas the Sundarbans represent the only population adapted to living in the mangrove forest habitat.

First tiger census in India

The estimate of tigers in the country has always been a wild guess. Gee (Wildlife in India, 1966) estimated the existence of 40,000 tigers at the end of the 19th century and about 4,000 tigers in 1965. According to Corbett (1955) the number of tigers was not >2,000. Sankhala (1970) estimated the number of tigers existing in the country to be about 2,500. However, a countrywide Tiger Census was done in the year 1972 to assess the status of the tiger, after the Survival Service Commission of the I.U.C.N. had drawn pointed attention to the threatened existence of the Royal Bengal tiger (*Panthera tigris tigris*) and the need for its complete protection. The result of the 1972 tiger census is given in Table below.

State	Number of tigers
1. Undivided Madhya Pradesh	457
2. Undivided Uttar Pradesh	262
3. Maharashtra	160
4. Assam	147
5. Odisha	142
6. Karnataka	102
7. Undivided Bihar	85
8. Nagaland	80
9. Rajasthan	74
10. West Bengal	73 (excluding 4/5th of Sundarbans)
11. Arunachal Pradesh	62
12. Kerala	60

State	Number of tigers
13. Undivided Andhra Pradesh	35
14. Tamil Nadu	33
15. Meghalaya	32
16. Gujarat	8
17. Tripura	7
18. Manipur	1
Total	1,820

Census techniques

The methodology adopted for this national census has been called the "Cooperation census". The method consists of the following basic operations:

The States having tiger habitats were grouped into five zones each under a Zonal Coordinator:

(i) Northern Zone: Uttar Pradesh and Bihar

(ii) Eastern Zone: West Bengal, Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, and Tripura.

(iii) Central Zone: Madhya Pradesh and Odisha.

(iv) Western Zone: Maharashtra, Rajasthan, Goa and Gujarat.

(v) Southern Zone: Tamil Nadu, Andhra Pradesh, Kerala and Karnataka.

The census was carried out in two stages:

(i) Eastern region from 22nd to 28th April, 1972; and

(ii) Rest of the country from 15th to 31st May, 1972.

Unfortunately, full details of the census regarding age-sex distribution of the tigers are not available and, as such, detailed analysis was not possible.

The above analysis of the various censuses highlights the following weaknesses in the conduct of various wildlife census and monitoring in India:

(1) Standard techniques for the census/estimation of different wildlife populations have not been evolved. Even in the same area the methodology followed for censusing the same population in two successive censuses has been changing depending upon the persons carrying out the census without examining various alternatives and studying the suitability of a particular type of method. As a consequence, the results, which are available, lack initial comparability and statistical reliability.

(2) Attempts at studying the structural aspects of wildlife populations as a part of census estimation are not properly emphasised. In this connection, studies in ageing and sexing of the population have to be developed further.

(3) Studies on 'natality' and 'mortality' are lacking, especially as a part of census study for purposes of studying population dynamics.

(4) Survival rates and age-specific mortalities for populations under study should form an essential part of population estimation.

(5) It is suggested that studies of population dynamics are immediately taken up for all the populations of animals which are rare or threatened and on the verge of extinction, like the black buck in Point Calimere where the results of the two census surveys reveal an almost complete absence of reproductive activity and consequent degeneration of the population. Similar studies will be needed for rare species like 'Hangul' in Kashmir (Dachigam), Swamp deer, the brow-antlered deer or the Sangai etc.

(6) A study of the age and sex structure of the lion and the tiger is also essential as the different census figures available show inherent contradictions.

(7) Census and monitoring operations as a regular management practice is on a different footing. The type of census estimation which is being made in the Palamau winter track census needs to be statistically refined as suggested in the paper so that results can be analysed on more scientific lines. It is suggested that similar continuous censuses may be made a part