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An Analytical Data-Driven Framework for Advancing Tiger Conservation in India

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Abstract

India is home to a significant population of the world's wild tigers, but it is disheartening to see that they are still classified as 'Endangered' on the IUCN's Red List. The efforts to protect these magnificent creatures are ongoing, with the Indian government working hand in hand with various Conservation organizations. Though we have seen some promising progress with a notable increase in tiger populations, it is not all smooth sailing. Challenges persist, including the loss of their natural habitats, the ever-present threat of poaching, and unfortunate conflicts between humans and these incredible animals.

This paper dives deep into the challenging mission of conserving tigers in India, highlighting the importance of forward-thinking strategies and using data-driven methods. We take a closer look at how data analytics can play a crucial role in conservation, from collecting and managing data to analysing it and making informed decisions. Our main goal is to offer practical recommendations on how to harness the power of data analytics to boost tiger conservation efforts in India, drawing on the most recent data trends and discoveries.

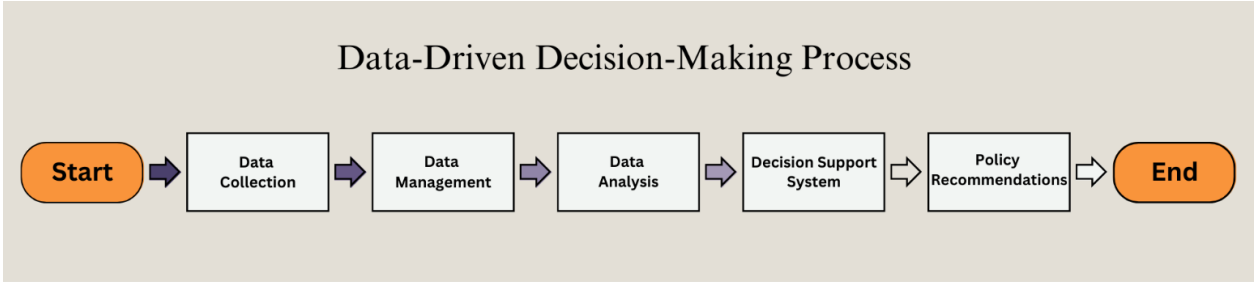
Keywords: Tiger Conservation, Data Analytics for Wildlife Conservation, Decision Support Systems, Wildlife Conservation Policy Recommendations, Conservation Technology

Introduction

The thriving population of Panthera Tigris, commonly referred to as the tiger, reflects India's remarkable biodiversity. Tigers are more than just charismatic apex predators; they are symbols of our country's ecological richness. As stated in a press release by the Indian Ministry of Environment, Forests, and Climate Change on July 29, 2023[1], India currently hosts around 75% of the world's wild tiger population. India commemorated the 50th anniversary of 'Project Tiger' at Mysuru on April 9, 2022. Our Honourable Prime Minister, Shri Narendra Modi, officially announced a minimum tiger population estimate of 3,167 tigers based on camera-trapped areas. On subsequent data analysis by the Wildlife Institute of India, encompassing camera-trapped and non-camera-trapped tiger habitats, the result indicated an upper limit estimate of 3,925 tigers and an average population of 3,682 tigers. The report declared an annual tiger population growth rate of 6.1%, drawing a notable triumph in our conservation efforts. Despite the increase in tiger populations, some regions, like the Western Ghats, experienced localized tiger population drops. Mitigating such declines needs better-targeted monitoring and conservation efforts. The report also stated that around 35% of the tiger reserves required immediate and enhanced protection measures. Big data and analytics methods for such enhanced protection can dramatically accelerate the progress of conservation efforts.**[2]**

During his speech in Mysore, the Indian Prime Minister pointed out that, although having only 2.4% of the world's land area, India contributes 8% of the world's known biodiversity. Yet, tiger conservation in India is an uphill battle and involves ecological, socio-economic, and geopolitical factors. Relentless encroachments by human activities have led to the loss of natural tiger habitats. Moreover, the persistent threat of poaching, fuelled by illegal wildlife trade networks, endangers tiger survival. Poachers mainly target tigers for their body parts used in traditional Chinese medicines and for luxury items derived from their fur.**[3]** Tiger habitats are rapidly vanishing, increasing tiger contact with human settlements. Unsurprisingly, human-wildlife conflicts are at an all-time high.

Knowing that such problems persist, we urgently need creative and collaborative efforts to protect and effectively oversee India's tiger populations. By providing a broad framework for using data analytics to bring about a transformative change in tiger conservation, we hope to contribute to well-informed strategies and decision-making tools. This framework covers every step of the data journey. i.e., From gathering data from diverse sources to employing advanced analytical methods for discovering patterns. We emphasize the importance of turning these insights into practical policy suggestions and stress the need for collaboration among various stakeholders, like researchers, conservationists, policymakers, and local communities.



We promote a comprehensive, science-based approach that enhances our knowledge of tiger behaviour and ecology. Using data analysis wisely, we can secure the future of these big cats in their natural habitats and reaffirm India's dedication to global biodiversity preservation. Figure (1) illustrates a simple

framework that shows all the phases involved in using data analytics for decision-making in Conservation. Let us now go over each of these phases in detail.

1. Data Collection

To use data analytics in any field, we first begin with gathering thorough and accurate datasets. These datasets form the building blocks of the data analytics approach because they ultimately determine the quality of our analysis. For the same reason, we must go beyond conventional data collection methods. Several new data-collection techniques, described below, have shown to be very effective in increasing the effectiveness of tiger Conservation efforts.

2.1. Camera traps: Motion-activated devices take photos and videos discretely while recording wildlife in their natural habitats. These recordings can help estimate tiger populations, carry out behavioural studies, and identify individual tigers based on their stripe patterns. Camera traps, coupled with Artificial intelligence algorithms, can automate species identification. ExtractCompare [4] is one of many such pattern recognition programs used by Indian conservationists. With their help, we can learn more about tiger movements, social interactions, and potential human-induced threats.

2.2. Satellite tracking: GPS collars are gaining immense popularity these days, and rightly so because they furnish real-time location data about tigers and offer priceless insights into their ecology.**[5]** Movement patterns of wild mammals, like tigers, can be easily studied with the help of GPS collars. These patterns can consequently enable the study of ranging behaviours, habitat preferences, and environmental interactions.

2.3. Acoustic Monitoring Networks: Devices that monitor sounds, like acoustic monitoring networks, help us to go beyond what our eyes can see.**[6]** They use a network of carefully placed microphones that record the unique sounds made by tigers and their potential prey. With the help of machine learning, we can analyse this audio to identify their vocalizations, differentiate between individual tigers, and even learn about their emotional states. As a result, we learn a lot about their social interactions, stress levels, and breeding behaviours.

2.4. Environmental DNA (eDNA) Sampling: Technologies like eDNA sampling allow us to non-invasively track the presence of tigers and count their numbers in desired areas. Researchers can collect water or soil samples from known tiger habitats to analyse the genetic material present in these samples. This method is both cost-effective [7] and gentle on the environment. Following that, tiger DNA traces found using advanced DNA sequencing techniques can be used for population assessment and monitoring. Monitoring tiger populations in remote or delicate ecosystems where directly observing them is difficult/not possible can be made easier with the help of such technologies.

2.5. Unmanned Aerial Vehicles (UAVs) and LiDAR technology: UAVs with LiDAR (Light Detection and Ranging) technology can perform highly detailed aerial habitat surveys **[8]** and can help conservationists learn more about tiger habitats. LiDAR has the remarkable capability to see through forest canopies and create intricate 3D maps of the landscape. These maps can identify concealed trails, water

sources, and potential poaching locations. Conservationists can pair LiDAR and UAVs to observe tiger movements and population densities, allowing real-time tracking of threats to tiger populations.

One power point about drones is that they can be programmed to fly in pre-determined routes in protected areas while capturing high-resolution images and videos. Using this, we can automate the detection of tigers and potential poachers by combining the powers of drones and AI-driven image recognition. Advanced machine learning models can sift through the captured imagery to identify tigers, count their numbers, and promptly alert forest rangers about suspicious human activities.

2.6. Climate and Habitat Data: For successful Conservation, it is not sufficient to only track tiger movements. Monitoring the changes in their habitat and considering the impacts of climate change are equally important. We must collect data on vegetation, water sources, and climate conditions as they can identify habitat degradation and potential threats to tiger survival.

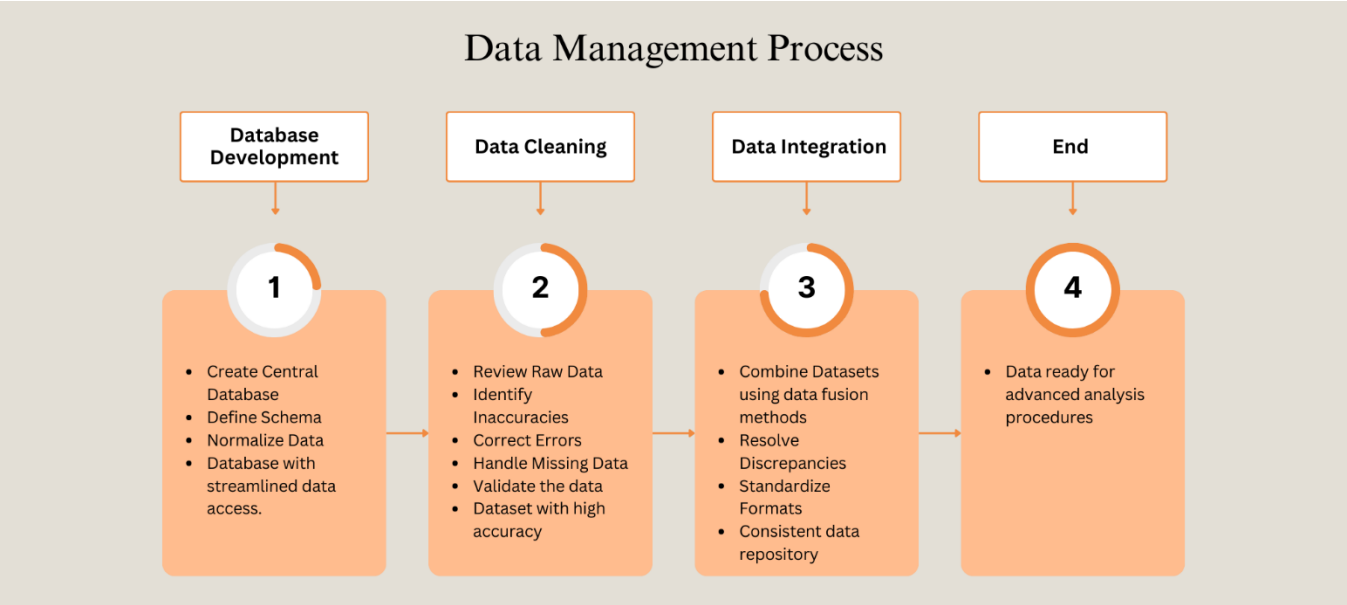
2.7. Metagenomics for Diet Analysis: To effectively manage tiger habitats, we must understand their eating patterns. Such learning is possible with the help of Metagenomic analysis **[9]** of scat samples. Researchers can use metagenomics to pinpoint the species consumed by tigers and evaluate the nutritional contents of their diets. Consequently, this aids in the identification of potential prey population declines and human-wildlife conflict hotspots. This knowledge can shape effective and robust conservation strategies.

2.8. Community-Based Data Collection: Involving local communities in data collecting is, to say the least, tremendously valuable. Localities can contribute their timeless wisdom and participate in citizen science initiatives. As such, communities can provide significant insights into tiger conservation. These include tiger sightings, behaviour, and potential poaching activities. Moreover, involving communities cultivates a sense of responsibility and ownership toward conserving these magnificent animals.

Integrating these data collection techniques into tiger conservation initiatives broadens the scope and richness of data that is accessible to us. Undoubtedly, technology is a powerful tool and can tackle the tricky issues of tiger conservation in India. It enables us to develop forward-thinking conservation strategies that can easily adjust to the changing world.

2. Data Management

We need a scientifically grounded approach to data handling if we want successful conservation results through data analytics. Data gathered from numerous sources forms the foundation for generating helpful analytical insights. Thus, proficient data management is imperative for ensuring data precision, credibility, and usefulness, and it is more than just a technical requirement.



In simple terms, data management is an efficient organization of data that makes it easily accessible and guarantees that it is readily available for decision-making. Data management includes several steps, covering database development, data cleaning, and data integration. Figure (2) shows the steps involved in the data management process. We will now go over the fundamentals of each of these steps.

3.1. Database Development: A centralized and well-organized database infrastructure is elemental for consolidating diverse datasets gathered from various sources. Databases are the repositories for all collected data. They consist of spatial, temporal, and categorical attributes. It is vital to design database schemas that follow data normalization principles **[10]** because this lowers redundancy and improves the efficiency of data retrieval. We can create a coherent data system using modern database management systems (DBMS) supported by relational database models. Also, adopting data standards and metadata conventions helps maintain semantic consistency. This results in more streamlined data access and enhanced interoperability in collaborative research projects.

3.2. Data Cleaning and Validation: The raw data acquired from field or sensor networks require thorough review and correction procedures to handle inaccuracies and discrepancies. Data cleaning and validation are a part of this procedure. Rigorous statistical techniques, such as outlier analysis **[11]**, hypothesis testing, and imputation algorithms **[12]**, are applied to rectify erroneous or incomplete data points. Involving domain-specific expertise in data-cleaning procedures improves dataset reliability. The primary goal of data cleaning is to produce a dataset marked by high accuracy that results in a robust foundation for following analytical processes.

3.3. Data Integration: Conservation data streams come from a myriad of sources. These include field surveys, satellite observations, acoustic sensors, and public contributions. Combining these different datasets to make one clear and organized system is necessary for analysis. And this is the job of data integration. Data integration necessitates the development of data fusion methods **[13]** that can resolve discrepancies. These differences may be in spatial and temporal resolution, sensor types, and data formats. For instance, Geospatial data integration may require geo-referencing datasets to a standardized coordinate

system. Spatial interpolation techniques can then harmonize varying spatial resolutions. We can use synchronization protocols to align data streams over time, ensuring consistency among data sources with temporal differences. Such well-maintained data repositories can help in tiger conservation by supporting evidence-based decision-making.

3. Data Analytics

Using data analytics in tiger conservation is a crucial paradigm shift in our conservation strategy. It brings precision, objectivity, and a strong focus on empirical evidence. By combining analytical techniques with powerful computational models, conservationists can understand the intricate ecological tapestry that affects tigers to make better-informed decisions.

Visualizations are the compass of data analytics, guiding us through landscapes of data. Charts like heat maps and trendlines help understand the current scenarios better. We will examine some analytical methods designed to uncover insights from the data we collect about tigers.

4.1. Spatial Analysis: Spatial analysis, aided by Geographic Information Systems (GIS) and remote sensing, helps understand the spatial dynamics of tiger habitats. GIS is the basis for identifying and characterizing critical tiger habitats, ecological corridors, and regions susceptible to human-wildlife conflicts. Geospatial data layers encompass land cover, topography, climate, and habitat suitability indices. Spatial analysis transcends mere visualization. It dives into complex spatial statistics, autocorrelation, and hotspot analyses.**[14]** It unveils patterns that explain the factors underpinning tiger distribution and movement. Hence, it provides a spatially unambiguous understanding of the ecological drivers shaping tiger populations.

4.2. Population Modelling: Population modelling **[15]** relies on wide-ranging data about tiger demographics, births, deaths, and their movements. Using mathematical and computational frameworks, researchers have the capacity to develop resilient population models. Researchers often use Leslie matrix models or agent-based simulations **[16]** to create these models. The models shed light on patterns, fluctuations, and predictions concerning the tiger population. They incorporate significant parameters like carrying capacity, mortality, and reproductive rate. They enable the development of conservation strategies rooted in observed evidence. Among these strategies are habitat management, reintroduction efforts, and initiatives focused on conservation breeding.

4.3. Poaching Detection: Illegal poaching is an insidious threat to tigers, and we must prioritize combating it. One strategy to prevent poaching is using machine learning algorithms **[17]** to identify covert poaching activities. By analysing extensive data from camera traps, algorithms capable of detecting irregularities and unusual patterns in tiger behaviour can be developed. These serve as indicators of poaching incidents. They can also differentiate between legitimate human presence and illicit activities. Proactive approaches like these for poaching detection enable swift response mechanisms. They solidify anti-poaching efforts and protect tigers from the negative consequences of illegal wildlife trading networks.

4.4. Human-Wildlife Conflict Analysis: A complicated relationship between ecological, social, and economic factors maintains the delicate balance between tigers and human populations. Data analytics is crucial for perceiving this intricate relationship. Researchers can identify areas where human-wildlife conflicts are most prevalent by comprehensively analysing conflict data. They can do so while considering where and when conflicts occur, socio-economic elements, and land use. These human-wildlife conflict heatmaps, extracted through statistical models and geospatial analyses, are the basis for specific mitigation strategies.**[18]** These strategies include community-driven conflict resolution, restoring natural habitats, and establishing early warning systems.

4. Decision Support Systems: Leveraging Data for Informed Conservation Strategies

A Decision Support System (DSS) is a computer-based tool or software that helps people make informed decisions. It relies on data analysis and modelling. DSS is central in using insights obtained from data analytics. They help evaluate various options and potential outcomes, leading to effective choices and bridge the gap between data-driven insights and actionable strategies. We shall now review a few DSS applications. i.e., Scientific risk assessment, scenario planning, and adaptive management strategies.

5.1. Risk Assessment: Assessing risks involves evaluating and quantifying various threats that tigers and their habitats face. This evaluation uses extensive datasets and advanced geospatial analyses. Usually, these risk assessment **[19]** models rely on Bayesian networks and machine learning classifiers. They synthesize an array of factors, including ecological elements, human activities, and climatic variables. They offer a means to quantify the likelihood and potential consequences of threats such as habitat loss and poaching. Risk assessment guides the prioritization of conservation initiatives. Therefore, it ensures the allocation of resources toward mitigating the most immediate threats.

5.2. Scenario Planning: Scenario planning **[20]** with the help of DSS is like looking into the future. It gives us ideas of what might happen by considering factors like climate change, land-use dynamics, and human-wildlife interactions. Tools like predictive modelling, ecological niche modelling, and agent-based simulations help conservationists create robust plans that withstand environmental changes. With scenario planning, conservationists adopt a proactive stance. They are ready for what might happen. Thus, they can manage things better, use resources wisely, and make more sapient policy formulations.

5.3. Adaptive Management: At the forefront of the DSS implementation stands the concept of adaptive management. It is a dynamic feedback loop **[21]**. It takes advantage of real-time data for continuous enhancement of conservation strategies. Adaptive management relies on continuous data acquisition, monitoring, and modelling to detect changing ecological dynamics and emerging threats. These systems effectively employ incoming data to refine and optimize conservation efforts through an iterative process. It involves statistical models, machine learning algorithms, and decision trees. Its adaptability enables rapid responses to unforeseen challenges. Therefore, conservation strategies will stay robust in changing ecosystems and human interactions.

5. Policy Recommendations: Advancing Tiger Conservation through Evidence-Based Strategies

We now present a set of evidence-driven policy suggestions that target strengthening tiger conservation initiatives in India. These recommendations are grounded in scientific rigor, empirical observations, and innovative approaches.

6.1. Strengthening Enforcement: Effectively enforcing measures against poaching and other illegal activities within tiger habitats can enhance Conservation **[22]**. Beyond conventional approaches, new techniques involve technologies such as drones with artificial intelligence (AI)-driven image recognition. Researchers can explore the efficiency of these AI-enhanced drones in enhancing surveillance capabilities, thereby substantially mitigating poaching activities. Predictive analytics can uncover patterns related to where and when poaching incidents occur. This information can help us take proactive measures through law enforcement. Moreover, when we combine knowledge from criminology and wildlife conservation, we can better understand the psychology of why poachers do what they do. This insight can help us develop more effective strategies to combat poaching.

6.2. Habitat Restoration and Corridor Protection: The restoration and protection of critical tiger habitats and corridors require visionary solutions. Ecologists can use sophisticated algorithms to pinpoint areas with the highest restoration potential.**[23]** These algorithms consider historical land use, soil composition, and ecosystem services, among other metrics. As they incorporate landscape genetics,**[24]** they can help safeguard corridors by evaluating the genetic connections between tiger populations. Advanced remote sensing tools, like hyperspectral imaging **[25]**, can detect early signs of habitat deterioration. This detection leads to proactive conservation actions. Habitat restoration through assisted natural regeneration using native plant species has advantages. It fits as a sustainable method for ecosystem restoration.

6.3. Community Engagement and Sustainable Livelihoods: We cannot stress enough the importance of Community-based conservation initiatives and promoting sustainable livelihoods for Conservation. Our researchers can focus on new ways to engage with local communities and study how they impact tiger conservation. For example, exploring measures to ensure equitable revenue sharing and evaluating the socio-economic effects of ecotourism on indigenous communities can foster community buy-in. Research that combines social sciences and Conservation can focus on two main things. The first is understanding how people and wildlife co-exist. The second is figuring out what makes these interactions positive. Research can aim to decrease human-wildlife conflicts through novel strategies. Bio acoustic deterrents **[26]** and digital early warning systems are some of them.

6.4. Research Priorities: Highlighting research priorities is essential to address knowledge gaps and steer conservation efforts effectively. Research can focus on non-invasive tracking of tigers using technologies like environmental DNA (eDNA) analysis.**[7]** Machine learning algorithms that automatically identify individual tigers based on their distinctive stripe patterns open new possibilities for population monitoring. Studies can investigate the ecological effects of climate change on tiger habitats, directing solutions for adaptive management. Analysing genetic diversity and resistance of tiger populations to environmental stressors may also be a top priority.

The policy recommendations presented above are not strict commandments. They are flexible, research-based approaches adaptable to the evolving context of tiger conservation. Embracing innovative methods and interdisciplinary collaboration can steer policy decisions toward data-driven, adaptive strategies. These strategies ensure the long-term prosperity of tigers in India. Such research contributes to the scientific understanding of tiger conservation. It also aids the practical commission of policies that resonate with complex human-tiger interactions.

6. Conclusion: Unleashing Data Analytics as a Catalyst for Tiger Conservation

As seen above, this paper highlights the transformative potential of data analytics in Indian tiger conservation. Beyond its theoretical importance, our study has far-reaching implications for on-the-ground conservation efforts. The power of analytics lies not solely in its capacity to generate insights but in its ability to catalyse tangible change. We advocate embracing innovative methods such as eDNA analysis, AI-driven monitoring systems, remote sensing, and interdisciplinary collaboration. This paper is a roadmap for conservationists, policymakers, and communities to navigate the intricate landscape of tiger conservation. Our findings stress the importance of collaborative governance models and community-led initiatives in fostering co-existence between humans and tigers. It sends a clear message to step up conservation efforts to stop poaching and unlawful activities within tiger habitats using technology for more effective surveillance.

This paper offers practical recommendations for conserving tiger habitats and ecological corridors, fostering tiger populations, supporting sustainable livelihoods, and ensuring equitable revenue-sharing among local communities. It takes a holistic approach, combining various data collection methods and advanced analytics, including spatial analysis, population modeling, poaching detection, and the study of human-wildlife conflicts. These insights create a comprehensive framework for conservationists and policymakers, enabling well-informed decisions to protect India's tiger population.

In the face of unprecedented ecological challenges, our study is a testament to the enduring spirit of Conservation. It beckons us to translate knowledge into action to defend the legacy of the tiger for generations to come. The future of these majestic creatures in India, and indeed in the world, depends on our collective dedication to the cause. As stewards of the natural world, we stand at a pivotal juncture. The journey ahead is one of discovery, resilience, and co-existence. A journey that champions the survival of tigers in India and sets an inspiring example for global conservation efforts. Through the strategic implementation of analytics, we can ensure that the tiger's roar continues to resonate through the forests of India. This roar echoes the promise of harmony between humanity and nature.

7. Acknowledgments

We extend our heartfelt gratitude to all the individuals and organizations who have made immeasurable contributions to tiger conservation in India. While this paper is rooted in a comprehensive literary review, it is a tribute to the shared efforts of these stakeholders. It would not have been possible without their unwavering commitment.

Our gratefulness goes to the field researchers who have bravely ventured into tiger habitats to gather critical data, the conservationists who work tirelessly to protect these magnificent creatures, and the local

communities who have shown a deep sense of responsibility and ownership toward tiger conservation. We also acknowledge the pioneering scholars whose research forms the foundation of our understanding of tiger behavior and ecology, as well as the technological innovators who have developed cutting-edge tools and techniques for tiger conservation. In addition, we express our appreciation to the policymakers who have taken steps to support conservation efforts and the funding agencies that have provided the resources necessary for this conservation efforts. Undoubtedly, collaborative conservation efforts are the way to go, and together, we stand as a ray of hope for the survival and thriving of this glorious species. It is through the collective efforts of all these individuals and organizations that we can continue to protect the legacy of the tiger in India for generations to come.

9. Citations

1. Ministry of Environment, Forest and Climate Change, India. All India Tiger Estimation - 2022: Global Tiger Day, Release of Comprehensive Tiger Report – at Corbett Tiger Reserve. Press Information Bureau Government of India. Retrieved from https://pib.gov.in/PressReleseDetailm.aspx?PRID=1943922#:~:text=India%20currently%20harbors%20almost%2075,decline%20due%20to%20extensive%20poaching.
2. Runting, Rebecca K., et al. "Opportunities for big data in conservation and sustainability." *Nature Communications* 11.1 (2020): 2003. https://doi.org/10.1038/s41467-020-15870-0
3. Nittu, George, et al. "The tide of tiger poaching in India is rising! An investigation of the intertwined facts with a focus on Conservation." *GeoJournal* 88.1 (2023): 753-766. https://doi.org/10.1007/s10708-022-10633-4
4. Hiby, Lex, et al. "A tiger cannot change its stripes: using a three-dimensional model to match images of living tigers and tiger skins." *Biology letters* 5.3 (2009): 383-386. https://doi.org/10.1098/rsbl.2009.0028
5. Miller, Clayton S., et al. "Review of research methodologies for tigers: telemetry." *Integrative Zoology* 5.4 (2010): 378-389. https://doi.org/10.1111/j.1749-4877.2010.00216.x
6. Wrege, Peter H., et al. "Acoustic monitoring for conservation in tropical forests: examples from forest elephants." *Methods in Ecology and Evolution* 8.10 (2017): 1292-1301. https://doi.org/10.1111/2041-210X.12730
7. Beng, Kingsly C., and Richard T. Corlett. "Applications of environmental DNA (eDNA) in ecology and conservation: opportunities, challenges, and prospects." *Biodiversity and Conservation* 29 (2020): 2089-2121. https://doi.org/10.1007/s10531-020-01980-0
8. Zahawi, Rakan A., et al. "Using lightweight unmanned aerial vehicles to monitor tropical forest recovery." *Biological Conservation* 186 (2015): 287-295. https://doi.org/10.1016/j.biocon.2015.03.031
9. Wei, Fuwen, et al. "Conservation metagenomics: a new branch of conservation biology." *Science China Life Sciences* 62 (2019): 168-178. https://doi.org/10.1007/s11427-018-9423-3
10. Hillyer, Mike. "An introduction to database normalization." *MySQL AB* (2003).
11. Aggarwal, Charu C., and Charu C. Aggarwal. *An introduction to outlier analysis*. Springer International Publishing, 2017. https://doi.org/10.1007/978-3-319-47578-3_1
12. Calabrese, Barbara. "Data cleaning." *Encyclopedia of bioinformatics and computational biology: ABC of bioinformatics* 472 (2018).

13. Brum-Bastos, Vanessa, et al. "Multi-source data fusion of optical satellite imagery to characterize habitat selection from wildlife tracking data." *Ecological Informatics* 60 (2020): 101149. https://doi.org/10.1016/j.ecoinf.2020.101149.
14. Wall, Jake, et al. "Novel opportunities for wildlife conservation and research with real-time monitoring." *Ecological Applications* 24.4 (2014): 593-601. https://doi.org/10.1890/13-1971.1
15. Tuia, Devis, et al. "Perspectives in machine learning for wildlife conservation." *Nature Communications* 13.1 (2022): 792. https://doi.org/10.1038/s41467-022-27980-y
16. Shiflet, Angela B., and George W. Shiflet. *Introduction to computational science: modeling and simulation for the sciences*. Princeton University Press, 2014.
17. Gurumurthy, S. et al. "Exploiting data and human knowledge for predicting wildlife poaching." *Proceedings of the 1st ACM SIGCAS Conference on Computing and Sustainable Societies*, June 2018, pp. 1-8.
18. Distefano, Elisa. "Human-Wildlife Conflict worldwide: collection of case studies, analysis of management strategies and good practices." *Food and Agricultural Organization of the United Nations (FAO), Sustainable Agriculture and Rural Development Initiative (SARDI), Rome, Italy. Available from: FAO Corporate Document repository http://www.fao.org/documents* (2005).
19. Siddayao, Generino P., et al. "Analytic hierarchy process (AHP) in spatial modeling for floodplain risk assessment." *International Journal of Machine Learning and Computing*, vol. 4, no. 5, 2014, p. 450. https://doi.org/10.7763/IJMLC.2014.V4.453
20. Peterson, Garry D., et al. "Scenario planning: a tool for conservation in an uncertain world." *Conservation Biology*, vol. 17, no. 2, 2003, pp. 358-366. https://doi.org/10.1046/j.1523-1739.2003.01491.x
21. McCarthy, Michael A., and Hugh P. Possingham. "Active adaptive management for conservation." *Conservation Biology* 21.4 (2007): 956-963. https://doi.org/10.1111/j.1523-1739.2007.00677.x
22. Kelaher, Brendan P., et al. "Strengthened enforcement enhances marine sanctuary performance." *Global Ecology and Conservation* 3 (2015): 503-510. https://doi.org/10.1016/j.gecco.2015.02.002
23. Cummings, Adam K., Karen L. Pope, and Gilbert Mak. "Resetting the Baseline: Using Machine Learning to Find Lost Meadows." [Preprint - Paper under review] (2023). https://doi.org/10.1007/s10980-023-01726-7
24. Segelbacher, Gernot, et al. "Applications of landscape genetics in conservation biology: concepts and challenges." *Conservation Genetics* 11 (2010): 375-385. https://doi.org/10.1007/s10592-009-0044-5
25. Fischer, Christian, and Ioanna Kakoulli. "Multispectral and hyperspectral imaging technologies in conservation: current research and potential applications." *Studies in Conservation* 51.sup1 (2006): 3-16. https://doi.org/10.1179/sic.2006.51.Supplement-1.3
26. Teixeira, Daniella, et al. "Bioacoustic monitoring of animal vocal behavior for conservation." Conservation Science and Practice, vol. 1, no. 8, 2019, e72. https://doi.org/10.1111/csp2.72