

GLOBAL BLACK MARKETS AND BLOOD RED FOREST FLOORS – AN EXPANDING CANVAS FOR THE ART OF FORENSIC SCIENCE”

AUTHOR – JENI BN* & SUGITH KUMAR**

* STUDENT AT SCHOOL OF EXCELLENCE IN LAW, THE TAMILNADU DR. AMBEDKAR LAW UNIVERSITY, CHENNAI

** PROFESSOR, SCHOOL OF EXCELLENCE IN LAW, THE TAMILNADU DR. AMBEDKAR LAW UNIVERSITY, CHENNAI

BEST CITATION – JENI BN & SUGITH KUMAR, GLOBAL BLACK MARKETS AND BLOOD RED FOREST FLOORS – AN EXPANDING CANVAS FOR THE ART OF FORENSIC SCIENCE”, *INDIAN JOURNAL OF LEGAL REVIEW (IJLR)*, 6 (2) OF 2026, PG. 945-964, APIS – 3920 – 0001 & ISSN – 2583-2344.

Abstract

“I suffer whenever I see the wilting plant” – Vallalar Ramalingar

The escalating crisis of wildlife crime presents a profound threat to global biodiversity, with illegal poaching, trafficking, and habitat destruction undermining conservation efforts and legal enforcement frameworks. This paper explores the critical role of forensic science in transforming wildlife crime investigations, particularly within the Indian context. By examining key forensic methodologies—such as DNA analysis, toxicology, veterinary pathology, and ballistic evidence—the study evaluates how scientific advancements have enhanced the accuracy and legal admissibility of wildlife crime evidence. It also interrogates the systemic and logistical challenges posed by remote crime scenes, lack of specialized training, and fragmented legal jurisdictions. A comparative analysis with human crime scene investigations reveals significant procedural and ecological differences that influence evidence collection and case outcomes. Despite the robust potential of forensic tools, the research identifies limitations in current enforcement mechanisms and calls for legal reforms, improved inter-agency coordination, and the establishment of dedicated wildlife forensic laboratories. Through case studies and policy evaluation, this study positions wildlife forensics not as an auxiliary tool, but as a foundational pillar in the fight against ecological crime and the preservation of endangered species.

Key Words : Wildlife Forensics, Ballistics, Toxicology, Veterinary Pathology, etc.

❖ Introduction; Defining Wildlife Forensics

“Sherlock then proceeded to determine who the killer was merely from browsing momentarily at the signatures of all the suspects.” Did he? I wouldn’t know. But we have all seen him perform equally improvise feats in his stories and movies. One can only hope that he wears on a rain jacket and sets out to protect the wildlife too! We needn’t just hope any longer.

Wildlife forensics is a specialized field that applies forensic science principles to the investigation of crimes involving wildlife,

including both animals and plants. It encompasses a broad range of activities aimed at protecting non-domesticated species, whether they are free-living or in captivity, and often extends to the conservation of their habitats. The field is interdisciplinary, drawing on expertise from veterinarians, biologists, ecologists, and legal professionals to gather and analyze evidence that can be used in legal proceedings. Wildlife forensics is crucial for addressing offenses such as poaching, illegal trade, habitat destruction, and cruelty to animals, all of which threaten biodiversity and

ecosystem health. The discipline ensures that evidence is collected, processed, and presented in a scientifically sound manner, adhering to legal standards to support prosecutions and conservation efforts.

The scope of wildlife forensics is vast, covering cases where wildlife is either the victim, the perpetrator, or a sentinel providing critical information about environmental or human activities. For instance, forensic techniques may be used to identify species from animal parts in illegal trade, determine the cause of death in poached animals, or investigate human-wildlife conflicts where animals harm humans or property. The field also addresses the welfare of captive wildlife, ensuring that animals are treated humanely and that their illegal capture or trade is prosecuted. Additionally, wildlife forensics plays a role in monitoring zoonotic diseases, where animals act as indicators of environmental hazards or disease outbreaks that could affect human health.

Methods in wildlife forensics mirror those used in traditional forensic science but are adapted to the unique challenges posed by wildlife cases. These include crime scene investigation, sample collection, genetic analysis, toxicology, and pathology. The field often operates in remote or challenging environments, requiring portable equipment and mobile laboratories to conduct on-site analyses. Accurate species identification, often using DNA technology, is a cornerstone of wildlife forensics, particularly in cases involving illegal trade or disputed origins of animal products. The discipline also emphasizes ethical considerations, ensuring that investigations respect animal welfare and conservation goals while upholding justice.

Wildlife forensics is an evolving field, shaped by changes in wildlife crime patterns, advancements in forensic technology, and shifts in legal and societal attitudes toward conservation. It plays a vital role in global efforts to combat wildlife crime, which is increasingly recognized as a serious threat to biodiversity, often linked to organized crime and significant

economic losses. By integrating scientific rigor with legal frameworks, wildlife forensics helps bridge the gap between conservation and law enforcement, ensuring that wildlife crimes are effectively investigated and prosecuted. The field's interdisciplinary nature and its focus on both justice and conservation make it indispensable in the fight to protect endangered species and ecosystems worldwide.

❖ Research Questions & Research

Hypothesis:

1. How does the integration of forensic science enhance the investigation and prosecution of wildlife crimes in India?
2. What are the key differences between wildlife and human crime scene investigations, and how do these differences influence forensic evidence collection?
3. To what extent can DNA analysis and toxicological forensics be relied upon to establish legal culpability in wildlife trafficking and poisoning cases?
4. What reforms are necessary in India's legal and enforcement systems to effectively incorporate forensic science in wildlife crime investigations?

This paper hypothesizes that despite the intrinsically difficult to prove nature of wildlife crimes and the persisting weariness of courts in accepting forensic science as evidence, forensic science will improve the traceability of the offender (solvability of crimes) at least, if not also the successful conviction rates.

❖ The Need for Forensics – Inherent Difficulty in Solving wildlife Crimes

1. Legal and Regulatory Weaknesses:

One of the primary hurdles in addressing wildlife crime is the significant legal and regulatory inconsistencies across regions. Wildlife crime legislation varies widely among countries, with different definitions and categorizations of offenses. This disparity allows traffickers to exploit legal loopholes and jurisdictions where enforcement is weaker. For instance, an act

considered illegal in one country may be legally ambiguous or even permitted in another, creating safe havens for traffickers.

Moreover, the misuse of permits under international agreements such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is prevalent. Traffickers often forge CITES documents or manipulate the system to pass off illegally sourced wildlife as legal. Permit fraud remains a serious issue, undermining the credibility of regulated trade.¹

Penalties for wildlife crime are often minimal, with many jurisdictions opting for small fines instead of incarceration. This approach fails to deter criminal activities and reinforces the perception of wildlife crime as a low-risk, high-reward endeavor. Strengthening punitive measures is essential to elevate the seriousness with which these crimes are treated.

2. Socio-Economic and Cultural Factors:

Wildlife crime is deeply rooted in the socio-economic and cultural fabric of many communities. In numerous regions, local populations depend on wildlife as a source of income or sustenance. Hunting, trapping, and trading wildlife are sometimes ingrained in tradition, creating complex ethical dilemmas for enforcement agencies. Banning these activities without providing viable alternatives may drive communities further into poverty and deepen their reliance on illegal trade.

Demand-side pressures also play a critical role. The appetite for exotic pets, traditional medicine, and luxury goods fuels illegal markets. Products like ivory, rhino horn, pangolin scales, and tiger bones continue to be sought after despite international bans². Without reducing consumer demand, efforts to curb supply are likely to fall short.

A fundamental challenge lies in the lack of economic incentives for conservation. In the absence of alternative livelihoods, such as employment in ecotourism or sustainable agriculture, communities may view wildlife as a

resource to be exploited rather than protected.

3. Enforcement and Logistical Barriers:

Enforcement agencies tasked with combating wildlife crime often face significant operational limitations. Many are underfunded, understaffed, and ill-equipped to patrol vast and often inaccessible protected areas. This inadequacy hampers their ability to conduct surveillance, investigate crimes, and prosecute offenders effectively.

Compounding the issue is the pervasive problem of corruption. In some cases, law enforcement officials and government representatives are complicit in trafficking operations, accepting bribes or facilitating smuggling efforts. These corrupt practices compromise investigations and erode public trust.

Additionally, the transnational nature of wildlife crime requires coordinated responses across borders, which are often hindered by bureaucratic inefficiencies and jurisdictional limitations. The lack of streamlined cooperation between different national and international agencies can delay or derail crucial enforcement actions.

Emerging trends making wildlife crime harder to stop:

1. Digital and Dark Web Trade

The digital revolution has introduced new challenges in combating wildlife crime. Traffickers increasingly rely on online platforms to conduct transactions, using social media sites and encrypted messaging applications such as Telegram and WhatsApp to communicate with buyers and sellers. These platforms offer anonymity, reach, and speed, making them ideal for illicit trade.

Cryptocurrencies have further complicated enforcement. Payments made through Bitcoin and other digital currencies are difficult to trace, enabling traffickers to move funds across borders undetected.³ The lack of regulation in this space adds another layer of complexity for

authorities.

2. Adaptive Criminal Networks

Wildlife trafficking networks are highly adaptive and responsive to enforcement pressures. As authorities crack down on the trade of iconic species such as tigers and rhinos, traffickers shift their focus to less-protected species, including reptiles, birds, and insects. These lesser-known species often receive minimal attention in legal frameworks, making them easier targets for exploitation.

Smuggling tactics have also evolved. Criminals increasingly employ the “ant trade” model, moving small quantities of wildlife products through various routes to avoid detection. These dispersed operations make it more challenging for customs and border officials to identify and intercept illegal shipments.

3. Legal Grey Areas in Trade

The global debate over the “sustainable use” of wildlife adds another layer of ambiguity.

Proponents argue that regulated trade can support conservation by generating revenue and reducing the incentive for illegal activities. Critics, however, contend that legitimizing trade perpetuates demand and provides cover for laundering illegally sourced animals and products⁴.

Captive breeding programs are another area of concern. While intended to reduce pressure on wild populations, these programs are sometimes used to launder wild-caught animals under the guise of legal breeding. The lack of stringent oversight and verification mechanisms undermines their intended purpose.

❖ Forensic veterinary pathology – An Essential Starting Point

Forensic pathology is the branch of medicine that investigates deaths to determine the cause and manner of death, often in cases of unnatural or suspicious circumstances. Thus, forensic veterinary pathology is the examination of

animals for evidence of diseases or injuries that may assist in legal proceedings. It seeks to determine the cause of death or injury and whether these were due to natural events or human intervention. This includes studying cases of trauma, poisoning, malnutrition, and animal welfare violations. Veterinary pathologists play a critical role in identifying whether an animal has been unlawfully injured or killed. This includes determining whether firearms, snares, traps, poisons, or other causes contributed to the death. For example, radiographs are useful for detecting bullets or metallic fragments in animals suspected of being shot.

Pathologists can assess wounds caused by firearms like shotguns, rifles, or air rifles. The analysis of entry and exit wounds, fracture patterns, and metallic fragments offers valuable forensic evidence to link a suspect to the crime. Forensic examination can also reveal the injuries caused by snares or traps—such as deep tissue damage or fractured bones. This helps investigators establish whether the use of these tools was illegal or resulted in unnecessary suffering to wildlife. Postmortem examinations are used to detect whether poisoning was involved in an animal’s death. Testing can identify pesticide residues or other toxic substances, which are then matched to evidence like poisoned baits found at crime scenes.

Veterinary pathologists often act as expert witnesses in court, providing unbiased and scientifically robust evidence. They document their findings meticulously and may be required to give testimony regarding the injury type and cause, the timeline of events such as the postmortem interval, and their professional opinion on whether an animal’s injuries align with illegal activities. Through their specialized skills, veterinary pathologists help build strong forensic evidence to connect suspects with crime scenes. They counter claims that injuries or deaths were accidental or due to natural causes and uphold wildlife protection laws by providing scientific clarity on contested issues.

These forensic methods have directly led to prosecutions in cases of illegal hunting, badger baiting, poisoning, shooting, and abuse of snares or traps. Each investigation benefits from the pathologists' ability to combine biological expertise with crime scene details and laboratory findings. Given below are case studies that help us understand how these techniques pan out in real life.

Case Study 1: Snares and Badgers

Badgers are frequently victims of illegal trapping using snares that fail to meet legal standards. In this case, a badger was found trapped in a snare that had become self-locking due to its design and prolonged entrapment. Upon forensic examination, veterinary pathologists identified severe injuries, including deep cuts and tissue necrosis, caused by the tightened snare. The badger had likely struggled for an extended period, resulting in significant suffering. The snare itself was examined and determined to contravene legal standards. This evidence was used to prosecute the individual responsible for setting the illegal snare, demonstrating that both the use of the snare and the resulting harm to wildlife were unlawful.

Case Study 2: Shooting of Birds of Prey

The forensic veterinary investigation into the shooting of a buzzard highlighted the use of advanced techniques such as radiography and ballistic analysis. The bird was found with metallic fragments in its body, consistent with shotgun pellets. Radiographs revealed fracture patterns in the bird's bones, confirming the injuries were inflicted by a firearm. Further analysis of the metallic fragments linked them to a specific type of shotgun used in such incidents. This evidence played a critical role in identifying the suspect and holding them accountable for illegally shooting the protected bird.

Case Study 3: Dog Bite Injuries

In cases involving wildlife attacked by dogs, forensic investigations play a vital role in

determining the cause and source of injuries. In this case, a protected species was found dead with bite injuries indicative of a dog attack. Veterinary forensic experts conducted a detailed examination of the bite patterns on the animal's body and performed DNA analysis on saliva traces found around the wounds. These tests linked the injuries to a suspect's dog, corroborating witness accounts and physical evidence. The findings led to successful prosecution, where the owner was held accountable for using the dog in illegal hunting activities.

Criminology is as vast a subject matter like law itself. The same can be said about forensics and by extension, wildlife forensics. Described below are sub-disciplines and practical aspects in this fascinating area of study which make its study a tad easier.

I. Crime Scene Management And Evidence Collection – How They Differ in Wildlife

Contexts:

Crime scene management in wildlife crime is a crucial and structured process aimed at preserving and investigating incidents involving the illegal exploitation of wild fauna and flora. These crimes, which violate international treaties like CITES and domestic laws such as the Wildlife Protection Act of 1972, can occur across multiple sites: the primary site where the animal is killed or trapped, the secondary site where the body or parts are processed, and the tertiary site where illegal trade or storage takes place. Upon arrival, the Investigating Officer (usually the Assistant Conservator of Forests) is tasked with promptly securing the site, notifying senior officials, and deploying a forensic team equipped with appropriate tools. The scene is then demarcated, access is restricted, and search patterns like grid or circle methods are implemented. Investigations follow a scientific approach that includes hypothesis formulation, evidence collection, and verification using forensic data and witness testimonies to establish the nature and scope of the crime.

Evidence collection in wildlife crimes involves

gathering a variety of materials, categorized into biological (e.g., blood, tissue, bones), chemical (e.g., poisons, pesticides), physical (e.g., weapons, snares), and trace evidence (e.g., fingerprints, tire marks, feathers). Each item is thoroughly documented, photographed, labeled, and stored in tamper-proof packaging to maintain its integrity.

Chain of custody is strictly followed, with every movement of the evidence recorded from the scene to the forensic lab to ensure its legal admissibility. Environmental details such as GPS location, temperature, and weather conditions are also documented. Legal compliance requires that at least two independent witnesses be present during searches or seizures, and investigators must maintain a daily case diary as per Section 172 of the Criminal Procedure Code to ensure procedural transparency and accountability.

Given the often-hazardous nature of wildlife crime scenes—ranging from exposure to dangerous animals and toxic substances to challenging terrain—investigators must use personal protective equipment and adhere to safety protocols. Forensic science plays a critical role in solving these crimes by applying morphological, molecular, toxicological, and ballistic analyses to identify species, causes of death, and connections between tools and suspects. Thorough search techniques, such as the use of sniffer dogs and planned search patterns (grid, spiral, line, or quadrant), enhance evidence recovery. Whenever possible, investigations are conducted in natural light for better visibility, and fragile evidence is protected against weather damage. Scene preservation, including security during off-hours, is vital to maintaining the credibility of the evidence and the overall success of the prosecution.

A Comparative Analysis: Wildlife Crime vs. Human Crime Scene Management:

The investigation and forensic examination of wildlife crimes diverge significantly from traditional human crime investigations. These differences arise due to varying ecological

settings, evidence profiles, enforcement structures, and procedural constraints. Understanding these distinctions is critical to building an effective and adaptable wildlife forensic framework.

A. Crime Scene Nature and Location

Human crime scenes are typically found in structured environments—residential, commercial, or urban locales—such as homes, streets, or industrial areas. These locations are usually more accessible and can be secured and processed with relative logistical ease. In contrast, wildlife crime scenes often span vast, remote, and ecologically diverse territories, including forests, wetlands, grasslands, or mountainous regions⁵. Investigators may encounter multiple crime-related zones:

Primary site: Where the animal was poached or trapped. Secondary site: Where the animal or its parts are processed.

Tertiary site: Where the illegal items are transported, stored, or traded.

Such fragmentation necessitates a broader geographical assessment and increased coordination between field units.⁶

B. Type of Evidence Encountered

While certain forms of evidence—such as blood, weapons, and fingerprints—are common to both wildlife and human crime scenes, wildlife investigations introduce a unique and ecologically specific spectrum of materials.

Wildlife crime scenes yield:

- Biological evidence: Animal remains like tusks, bones, feathers, or skins.
- Chemical evidence: Traces of poisons, pesticides, or tranquilizers.
- Physical tools: Snares, traps, or makeshift weapons.
- Ecological trace evidence: Animal footprints, droppings, or nesting disruptions.

Furthermore, forensic goals shift in focus. Unlike human investigations, where DNA testing is

used for personal identification, wildlife forensics emphasizes species and subspecies identification, often for the purpose of verifying protected status or origin.⁷

C. Investigative Personnel and Equipment

In cases of human crimes, the scene is managed by trained personnel such as police officers, forensic scientists, and specialized crime scene units with standardized training in criminal justice and evidence handling. Wildlife crimes, however, fall under the purview of forest officers and wildlife enforcement teams, notably the Assistant Conservator of Forests (ACF) or other regional officers⁸. These professionals, while skilled in tracking and ecological management, may lack formal forensic training.

To overcome environmental limitations, investigators carry portable wildlife crime scene kits containing gloves, evidence bags, GPS units, sample containers, digital cameras, and species-specific handling tools. These kits are customized for rugged terrain and for preserving organic matter that may degrade quickly due to exposure.

D. Scene Preservation and Access Control

Human crime scenes benefit from well-established police cordons, controlled entry, and often take place within enclosed environments. Conversely, wildlife crime scenes present substantial challenges in preservation due to open landscapes and dynamic natural conditions.

To manage this, investigators establish boundaries using ropes, flags, or tape, and regulate entry via a Common Approach Path (CAP) to prevent trampling of evidence. Ensuring chain of custody—a critical component for legal admissibility—is particularly challenging under these conditions due to weather, terrain, and animal interference⁹. Detailed documentation, witness corroboration, and photo-logging are essential to counterbalance these difficulties.

E. Legal and Witness Protocols

Human crime investigations operate within well-defined legal frameworks such as the Bharatiya Nyaya Sanhita and Bharatiya Nagarik Suraksha Sanhita. They benefit from established police stations, legal teams, and judiciary proximity. In contrast, wildlife crimes must align with environmental legislation such as the Wildlife Protection Act (WPA) of 1972, alongside the procedural standards outlined in the BNSS.

Given the remote nature of wildlife crimes, at least two independent local witnesses are often required during evidence collection or arrests to ensure procedural transparency. A case diary, maintained under Section 192 of the BNSS, serves as an official record of all investigative activities. This hybrid legal dependency necessitates that forest officials be adept not only in ecological knowledge but also in legal compliance.

II . Wildlife Toxicology – Studying Poisoning as an Assailant

Forensic toxicology involves identifying contaminants like pesticides and heavy metals in animal carcasses, baits, or environmental samples. In other words, it involves applying analytical chemistry to detect toxins in biological specimens for legal purposes. Techniques such as liquid chromatography–mass spectrometry are employed to detect carbamates like carbofuran and organophosphates like mevinphos, while scanning electron microscopy with energy-dispersive X-ray is useful for confirming the presence of metals, as might be needed in cases involving gunshot wounds.

In the context of wildlife crimes, forensic toxicology is used to distinguish between situations of approved use—where accidental poisoning may occur due to legal pesticide application—and instances of misuse or abuse. Misuse might refer to negligent overuse or incorrect application, whereas abuse involves deliberate poisoning, such as the intentional lacing of baits with banned pesticides. The legal

significance of toxicological evidence is highlighted by its necessity to meet judicial standards, including maintaining a strict chain of custody and utilizing accredited laboratories, such as Fera Science or SASA. This evidence supports prosecutions under legislation like the Wildlife and Countryside Act of 1981, the Control of Pesticides Regulations of 1986, and under provisions of international agreements such as CITES.

There are two cases capable of helping us understand how toxicological studies play out in real life when it comes to conviction of wildlife crimes. One key case involved the poisoning of red kites, where two adult red kites were discovered dead in the countryside near a bait station. Investigators noted a key detail: the presence of numerous dead insects on the bait, which suggested that a potent pesticide had been used. Despite the birds exhibiting no visible external trauma, tissue samples collected from the carcasses and residues from the bait sent to the **Wildlife Incident Investigation Scheme** and analyzed by the **Wildlife Incident Unit at Fera** confirmed the presence of mevinphos. Mevinphos is an organophosphate pesticide banned in the United Kingdom owing to its extreme toxicity, and its detection offered clear evidence of poisoning. However, the remote nature of these incidents, coupled with a lack of tangible evidence such as fingerprints on the bait, complicated the process of identifying and prosecuting the perpetrator. This situation underscores the need for enhanced forensic methods, including environmental DNA sampling and improved surveillance techniques in high-risk areas.

The second case, regarded as a landmark incident in Scotland, (the largest-ever carbofuran seizure in Scotland (10.5 kg) linked to a gamekeeper), centered around the discovery of a substantial cache of carbofuran during the investigation into wildlife deaths on a grouse moor. A search warrant on a gamekeeper's property led to uncovering 10.5 kilograms of the banned pesticide, along with syringes and other

items suggesting the deliberate preparation of a "poisoner's kit." Subsequent chemical tests revealed traces of carbofuran on the syringes, linking the tools directly to the poisoning process. The staggering volume of carbofuran found indicated systematic and potentially industrial-scale abuse, likely aimed at protecting gamebird populations by eliminating predatory species such as birds of prey. Although the gamekeeper was convicted under laws governing the possession of banned pesticides—and even faced charges under firearms regulations—the absence of direct evidence like fingerprints or witnessed poisonings limited the severity of the charge to a heavy fine rather than more extensive penalties. This case highlights significant investigative challenges and has fueled discussions about broadening legal liabilities to include landowners for crimes committed on their property, while also calling for stricter storage regulations and routine estate inspections.

Both cases illustrate the indispensable role of toxicological evidence in wildlife poisoning incidents. The presence of banned substances such as mevinphos and carbofuran in affected animals and materials definitively confirms poisoning, yet the difficulties in obtaining corroborative physical evidence often result in prosecutions that fall short of directly linking a suspect to the crime. These investigations reveal a broader theme: while advances in forensic science have enabled the clear identification of toxic agents in wildlife, the very nature of these remote and isolated events necessitates further development of field forensic techniques to capture more definitive evidence.

The implications for legal proceedings are substantial. Robust toxicological evidence provides a solid foundation for prosecutorial actions, yet, without additional circumstantial or physical evidence, legal outcomes are invariably limited. This dichotomy not only hampers more severe legal repercussions but also serves as a deterrent for potential future

offenders by highlighting gaps in current forensic and regulatory practices. Moving forward, there is a pressing need for both technological innovation and legislative reform. Research into non-invasive tools such as environmental DNA and modern monitoring technologies like drone surveillance could significantly enhance evidence collection in remote locations. Meanwhile, policy reforms which tighten the regulation of pesticide sales, enforce stricter storage protocols, and allow for enhanced liability measures for landowners could foster a more effective deterrence against future wildlife crimes.

The quantitative analysis of carbofuran in golden eagles and the corroborative evidence provided by insect mortality near bait in the case of red kites exposed to mevinphos, illustrate how toxicological analyses help classify incidents into categories of approved use, misuse, or deliberate abuse. Despite these detailed procedures, there exists a difficulty of linking toxins to specific perpetrators when supplementary evidence, like fingerprints on pesticide containers, is lacking. This approach differs from human-focused toxicology by emphasizing the analysis of non-target species, considering the factors of environmental persistence—such as secondary poisoning from lead shot—and incorporating field indicators like insect mortality near bait sites.

Case Study 1: DNA Traceability in the Captive Tiger Trade – The TigerBase Initiative:

A. The Challenge of Laundered Tigers

In Southeast Asia, a growing number of commercial tiger breeding facilities has led to increasing concerns about the laundering of wild-caught tigers into captive populations. These facilities often breed tigers under the claim of legality, while in reality, they may serve as cover for trafficking wild specimens or producing body parts for the black market. Law enforcement agencies find it difficult to verify whether a tiger has been legally bred in

captivity or illegally sourced from the wild, especially when visual examination or documentation is easily manipulated.

B. Forensic Solution: DNA Profiling and Parentage Testing

To address this challenge, the TRACE Wildlife Forensics Network initiated the TigerBase project, which implements a DNA-based registration and traceability system for all captive tigers in the region. TigerBase relies on Single Nucleotide Polymorphism (SNP) markers, which provide highly individualized genetic profiles that can:

1. Identify individual tigers with precision.
2. Establish parent-offspring relationships, helping to confirm legitimate captive breeding claims.
3. Match seized body parts or products to known animals in breeding facilities.

DNA samples (blood, tissue, hair) are collected from captive tigers and entered into a centralized, secure database. If authorities seize tiger parts during an investigation, forensic labs can compare the DNA of these items with registered profiles in TigerBase to determine if the tiger was from a known captive population or potentially from the wild.

C. Implementation and Impact

The TigerBase system is currently being implemented in Thailand, Malaysia, and Vietnam in partnership with national wildlife authorities. It allows:

1. Routine auditing of breeding claims.
2. Monitoring of population genetics within captive facilities.
3. Evidence-based enforcement of CITES regulations concerning trade in tigers and their derivatives.

The initiative represents a shift from reactive to preventive enforcement, aiming to remove ambiguity in tiger trade and bolster legal deterrents. Importantly, it demonstrates the feasibility of using forensic science at a national scale to regulate complex wildlife trade

networks.

Case Study 2: Forensic Tools in Combatting IUU Fishing and Seafood Fraud:

A. The Global Threat of IUU Fishing

IUU fishing is estimated to account for approximately 20% of all global fish catch, costing the global economy billions annually. It undermines fisheries management, depletes marine ecosystems, and contributes to organized criminal activity. The seafood industry's extensive processing and globalization make it easy for illegally caught fish to be laundered into the legal market. Once processed—e.g., into fillets, powders, or frozen goods—fish species become nearly impossible to identify visually, complicating traceability and regulation.

B. Forensic Science as a Solution

To combat IUU fishing and seafood fraud, wildlife forensic laboratories employ a suite of scientific tools: DNA Barcoding: A technique used to identify fish species from genetic material, even in heavily processed samples. This helps detect species substitution or the illegal trade of protected fish.

Stable Isotope Analysis: This method examines variations in chemical isotope ratios (like oxygen, carbon, and nitrogen) that differ by geography. These signatures can often reveal the ocean region from which a fish was harvested.

Morphological and Chemical Profiling: Used where intact features are present or where chemical additives and residues might suggest origin or handling method.

These methods have successfully identified illegally traded marine species such as:

1. Manta rays, targeted for their gill rakers.
2. Shark fins, often obtained from protected species.
3. Totoaba swim bladders, illegally harvested from an endangered fish species in Mexico.
4. Abalone, a high-value marine delicacy

subject to rampant poaching.

C. NOAA Fisheries Forensics Laboratory: A Case in Action

The NOAA Fisheries Forensics Laboratory in the United States is a leader in marine wildlife forensics. Between 2020 and 2022, NOAA conducted over 145 forensic investigations involving more than 1,525 evidence items. These included analyses of fish products intercepted at borders, from commercial markets, and in support of federal prosecutions.

For example, in several cases, DNA analysis uncovered mislabeled seafood products that claimed to be from sustainable fisheries but were in fact IUU-sourced. In other instances, forensic evidence has helped prosecute illegal exporters who falsely declared species or origins on customs paperwork.

III. A. Species Identification

Species identification is a critical component of wildlife forensic investigations, particularly in contexts where animal parts or derivatives are involved. The complexity of identifying species from processed or partial remains is well illustrated through various case studies, each highlighting distinct challenges and investigative approaches.

One notable example involves the unregulated seahorse trade in Brazil.¹⁰ In this case dried seahorses, listed under Appendix II of CITES, were being traded primarily for traditional medicine and souvenirs. In their market surveys across northeastern Brazil, they discovered that most seahorses were obtained as bycatch in shrimp fisheries and were often sold in poor preservation states. The researchers identified multiple species in trade, including *Hippocampus reidi* and *H. erectus*, using morphological characteristics such as body ring counts and coronet shape. Because traders and buyers often lacked awareness of legal regulations, seahorses were sold without permits, making enforcement difficult. This case underscores the need for reliable morphological keys and, where possible, DNA reference

libraries to support species identification in dried or degraded specimens.

A similar challenge was observed in the marine curio trade, where Dias et al. (2011) conducted an extensive survey of ornamental molluscs being sold in tourist markets across Natal City, northeastern Brazil¹¹. They identified 126 species—85 gastropods and 41 bivalves—many of which are endemic to the Atlantic coastline. Identification was based solely on shell morphology, with particular attention paid to coloration, sculpture, and shell size. The trade operated without licensing or sustainability assessments, and many of the species found are believed to be vulnerable or at risk of overharvesting. The case highlights the importance of local taxonomic expertise and the potential for integrating forensic science with conservation assessments. It also draws attention to the limitations of traditional identification methods when specimens are altered or polished for commercial appeal.

Another example demonstrates how species identification can be integrated with human DNA profiling to build stronger forensic cases. Tobe et al. (2011a) investigated a poaching incident in which deer had been illegally killed¹². Although identifying the species of deer—such as *Cervus elaphus* or *Capreolus capreolus*—was straightforward, this alone was insufficient for legal action due to legal hunting allowances during certain seasons. The novel aspect of the study was the attempt to extract human DNA from the deer carcasses, specifically from areas like the legs, where poachers had handled the animals. Using swabbing techniques and short tandem repeat (STR) profiling, they successfully retrieved complete or partial human DNA profiles, even from samples left exposed in the environment. This proof-of-concept showed that linking a suspect to a carcass through human DNA could provide powerful corroborative evidence in poaching prosecutions³.

Finally, a high-profile ivory seizure in Singapore (2002) exemplifies the cutting-edge use of

genetic analysis in species and population-level identification. In this case, 6.5 tons of African elephant ivory were intercepted, making it one of the largest ivory seizures since the 1989 international ban. Wasser et al. (2007) used DNA analysis from the tusks to determine the geographic origin of the ivory. By comparing mitochondrial and nuclear DNA from the seized tusks to a reference map of elephant genotypes across Africa, they determined that the ivory originated primarily from elephants in Zambia, Malawi, and Tanzania. This allowed law enforcement agencies to identify poaching hotspots and assess the efficiency of anti-poaching efforts. The ivory was ultimately destroyed in Kenya in 2011 as a symbolic act against wildlife crime. This case illustrates how forensic genetics can inform not just species identification, but also population tracking and international enforcement strategy.

These cases collectively emphasize the multifaceted role of species identification in wildlife forensics, from traditional taxonomy to cutting-edge molecular biology, and highlight the need for adaptable methodologies to address diverse forensic contexts.

III. B. The Role of DNA Analysis in Particular

DNA analysis has revolutionized the field of wildlife forensics, offering a scientifically robust means of addressing the complex challenges associated with investigating wildlife crime¹³. Unlike traditional criminal investigations, wildlife crimes often occur in remote areas with few or no human witnesses. DNA forensics compensates for this lack of direct evidence by providing definitive biological links between suspects, crime scenes, and the animal or plant species in question. Several methods are employed depending on the investigative goals, including species identification, individual and parentage testing, and determining geographic origin.

Species identification through DNA testing allows forensic scientists to determine the exact biological classification of an animal or plant specimen, even when only parts or derivatives

(such as feathers, fur, bone, or meat) are available. This is particularly useful in cases involving the illegal trade of endangered species where visual identification is impossible or inconclusive.

Individual identification is akin to fingerprinting in human forensic science. Each animal's DNA is unique (barring clones or identical twins), allowing investigators to match seized body parts—such as horns or tusks—to a specific poached animal. This method has proven crucial in building cases that directly link suspects to poaching incidents.

Parentage analysis is often used to verify claims of captive breeding, which is legal under many wildlife trade laws, versus wild capture, which is not. Breeders may falsely declare wild-caught animals as captive-bred to circumvent regulations. DNA testing can confirm whether an animal is genetically related to the claimed parents, exposing fraudulent claims.

Finally, DNA analysis—sometimes in combination with isotope or environmental DNA (eDNA) testing—can help determine the geographic origin of a specimen. This is vital for enforcing international agreements like the Convention on International Trade in Endangered Species (CITES), which regulates trade based on both species and country of origin. Overall, the use of DNA in wildlife crime investigations strengthens prosecutions, supports international enforcement efforts, and acts as a deterrent to traffickers.

Key Case Studies Demonstrating the Impact of DNA Forensics Rhino Horn DNA Typing

One of the most powerful applications of DNA analysis in wildlife crime has been in the illegal trade of rhino horn. In a notable case detailed in the guide, enforcement officers used DNA forensics to determine the species and individual identity of a rhino from which a seized horn originated. The horn was being sold illegally online. Scientists were able to match its DNA profile to a specific rhino that had been documented as poached in Africa. This direct

link between the seized item and a poached animal provided incontrovertible evidence of illegal activity and was instrumental in obtaining a conviction. The case exemplifies how DNA can not only identify the species but also reconstruct the chain of events, effectively dismantling trafficking claims of legal origin.

Birds' Egg Collection Fraud

Another case illustrating the importance of DNA forensics involved the prosecution of a collector who possessed a large cache of protected birds' eggs. The collector attempted to obscure the illegality of his possession by labeling the eggs with false dates, implying they had been collected before wildlife protection laws came into effect. In addition to handwriting analysis used to link the collector to the labels, DNA tests on the eggshells helped establish that the eggs had been taken recently and could not possibly predate the legislation. The forensic evidence demonstrated deliberate deception and was a pivotal factor in securing a guilty plea and sentencing. This case highlights how DNA evidence can disprove fraudulent provenance and strengthen legal proceedings in otherwise difficult-to-prove wildlife cases.

Radiocarbon Dating of Ivory alongside DNA

Although not solely a DNA case, another notable investigation combined radiocarbon dating and DNA testing to determine the legality of ivory being sold online. Under international and national laws, only ivory acquired before a certain date (often 1947 or 1976, depending on the country) can be legally traded. In this case, the seller claimed the ivory was antique. Radiocarbon dating revealed it was taken from an elephant killed after the legal cut-off, and DNA testing confirmed it was from an African elephant—a protected species under CITES. The use of DNA in conjunction with other forensic methods helped prove both species and illegal timing of acquisition, directly countering the seller's defense.

IV. Firearm Analysis in Wildlife Crime Investigations

Firearm analysis is an essential tool in wildlife crime investigations, enabling enforcement agencies to connect weapons, ammunition, and ballistic evidence to suspected illegal activities involving wildlife. The document elaborates on how firearms and ballistic investigations contribute to understanding and prosecuting cases of wildlife crimes such as poaching, illegal shooting, and targeted killings of protected species.

Ballistic Evidence and Investigation

Ballistic evidence, including shotgun cartridges, bullet fragments, and pellets, is crucial for identifying the type of weapon used in wildlife crime. Experts analyze the rifling marks on bullets, damage patterns on wildlife carcasses, and shooting distances to establish links between suspects, crime scenes, and illegal activities. For instance, firearms experts assess whether a particular weapon fired the recovered ammunition or bullet fragments.

Role of Postmortem Examination

Forensic veterinary pathologists collaborate with firearms experts in cases involving gunshot wounds to wildlife. Postmortem examinations reveal the trajectory of bullets and identify the type of ammunition used. Radiographs (X-rays) are employed to locate metallic fragments and trace injuries. This information is vital in confirming the use of firearms and establishing cause of death. Additionally, injuries like bone fractures and metallic residues provide evidence of shooting incidents.

Firearm Linking Techniques

Recovered firearms are matched to bullets and cartridge cases using specialized forensic techniques such as ballistic microscopy. Experts analyze unique patterns imparted by the barrel of a firearm on the discharged bullet or cartridge case. These markings act as a "fingerprint" for each weapon, enabling investigators to connect it to specific crime scenes.

Examples of Firearm Analysis

Case 1: Badger Shooting Case

In this case, multiple badgers were found dead with gunshot wounds. Veterinary forensic pathologists conducted postmortem examinations and recovered bullet fragments from the carcasses. These fragments were analyzed using ballistic microscopy to identify the type of firearm used. While the analysis could not conclusively match all fragments to a specific weapon, it successfully ruled out certain firearms, narrowing the scope of the investigation. This evidence was pivotal in focusing the inquiry on a smaller pool of suspects.

Case 2: Cormorant Shooting Incident

This case involved the illegal shooting of cormorants, a protected species. Forensic experts retrieved bullets from the carcasses and conducted ballistic analysis to trace the projectiles to a specific rifle. The investigation revealed that the rifle was owned by a suspect, providing direct evidence linking the individual to the crime. This conclusive ballistic evidence led to the successful prosecution of the suspect.

Case 3: Hen Harrier Case

The Hen Harrier case is a notable example of firearm analysis in wildlife crime. Shotgun cartridges were recovered from the scene where a hen harrier, a protected bird of prey, was found shot. Ballistic experts matched the cartridges to a shotgun seized from a suspect. This evidence, combined with witness testimonies, provided a strong case against the individual. However, specific details regarding the suspect's identity or judicial citation are not readily available.

Challenges in Evidence Handling

The integrity of ballistic evidence is crucial for successful prosecution. Issues such as improper handling or loss of evidence can undermine investigations, as evidenced by cases where vital ballistic evidence was misplaced, leading to case abandonment.

Technological Advancements

The National Ballistics Intelligence Service (NaBIS) plays a pivotal role in firearms-related investigations. Its database and hubs facilitate tracking firearms and ballistic material across the UK. Integrated Ballistics Identification System (IBIS) technology enables the automated linking of bullets and cartridge cases to recovered weapons, streamlining investigations.

V. Forensic Palynology and Its Role in Wildlife Crime Investigation

Forensic palynology refers to the application of palynology—the study of microscopic biological particles such as pollen grains, plant spores, and fungal spores—within a forensic context. These particles are omnipresent in natural environments and exhibit a high degree of durability, environmental specificity, and taxonomic variability, making them ideal indicators of geographic origin and environmental exposure.¹⁴

In the investigation of wildlife crime, forensic palynology serves as a powerful complementary tool, particularly in cases where traditional forms of evidence such as eyewitness accounts, fingerprints, or direct surveillance are absent. Since many wildlife crimes occur in remote or natural environments, the presence and composition of pollen and spores on suspects, animals, or tools can serve as trace evidence, linking individuals to specific crime scenes or habitats.

Forensic palynologists analyze palynological samples recovered from a variety of sources, including clothing, vehicles, tools, feathers, fur, and even the digestive tracts of animals.

A notable example involved a man suspected of illegally digging into a badger sett (a badger's underground home). Investigators found shovels in his car, which were dirty with soil. When scientists examined this soil, they found pollen and fungal spores—some from truffles a type of underground fungus—that matched samples from the badger sett. This

strongly indicated the spades had been used at that specific location. Additionally, DNA testing confirmed that hair found on the spade came from a badger. These combined forensic findings were used in court, and the man was successfully convicted.

While the specific name of the case is not publicly known, it is documented as the first successful prosecution for badger-digging facilitated by the RSPCA (Royal Society for the Prevention of Cruelty to Animals). The incident took place in the Staffordshire countryside, and the presence of the rare truffle fungus, *Choiromyces meandriformis*, on the suspect's spade was a crucial piece of evidence that linked him directly to the crime scene.

In addition to locating individuals within a specific environment, forensic palynology can help determine the season during which a crime may have occurred, as many plant species release pollen only during particular periods of the year. Moreover, in the context of wildlife trafficking, palynological evidence on packaging material or specimens can assist in establishing the geographical origin of illegally traded flora and fauna, thereby strengthening the prosecution's case and facilitating compliance with international wildlife trade regulations such as CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1975).

It is important to note that palynological investigations require significant expertise and resources. The identification process involves microscopic analysis, typically using light or phase-contrast microscopy, and comparison with reference samples from known locations. While the identification of pollen is often limited to the genus or family level, the unique combination of palynomorphs in a given sample can effectively place a suspect or object within a particular environment.

In conclusion, forensic palynology is an underutilized yet highly effective tool in wildlife crime investigation. It provides scientific, location-specific evidence that can corroborate

other investigative findings, eliminate alternative hypotheses, or generate new lines of inquiry. Its application underscores the interdisciplinary nature of wildlife forensics and reinforces the value of combining ecological science with legal enforcement mechanisms.

❖ Key International Organizations Supporting Wildlife Forensics

A few organizations that strive hard to expand the scope of forensics to serve a better purpose are described as under:

1. TRACE Wildlife Forensics Network

TRACE Wildlife Forensics Network, based in the United Kingdom, stands as a pioneer in the integration of forensic science into wildlife crime investigations. As an independent, non-governmental organization, TRACE focuses on enhancing forensic capacity in regions most impacted by illegal wildlife trade. It does this through targeted training, collaborative research, and infrastructure support.

One of TRACE's flagship initiatives is the TigerBase project, which seeks to combat the laundering of wild tigers into the captive breeding industry. Through a secure DNA registration system, TigerBase enables enforcement agencies in Southeast Asia to verify breeding claims and match seized specimens to registered individuals. The initiative not only acts as a deterrent to illegal breeding operations but also empowers national authorities with forensic evidence to support legal action.¹⁵

Beyond this, TRACE has facilitated the establishment of regional wildlife forensic networks, including in Africa and Southeast Asia. These networks encourage collaboration among scientists, enforcement officers, prosecutors, and policymakers. TRACE's work also involves providing reference materials, validation protocols, and standard operating procedures (SOPs), which are essential to ensure consistency and quality in forensic testing. TRACE is a driving force behind efforts to make forensic science accessible and impactful in

wildlife protection.

2. United Nations Office on Drugs and Crime (UNODC)

The United Nations Office on Drugs and Crime (UNODC) plays a pivotal role in promoting global strategies to combat transnational environmental crimes. Within its broader mandate to address illicit drug trafficking and organized crime, UNODC operates the Global Programme on Crimes that Affect the Environment, which encompasses wildlife and forest crime.

UNODC's contributions to wildlife forensic science are multifaceted. The organization develops training materials, hosts capacity-building workshops, and publishes guidelines to ensure that evidence collected during wildlife crime investigations meets legal standards. One notable publication is the Wildlife Crime Scene Guide, designed to help first responders document, collect, and preserve evidence at remote or difficult crime scenes. The guide has been translated into multiple languages and adopted by enforcement agencies worldwide.

As a key member of the International Consortium on Combating Wildlife Crime (ICWC), UNODC works alongside INTERPOL, the World Bank, the World Customs Organization, and the CITES Secretariat to deliver coordinated support to countries tackling wildlife crime.¹⁶ Through ICWC's Wildlife and Forest Crime Analytic Toolkit, UNODC helps countries assess their enforcement frameworks and identify gaps in their forensic capabilities. These comprehensive efforts ensure that wildlife forensics is not only scientifically rigorous but also aligned with judicial and policy systems globally.

3. US Fish and Wildlife Service Forensics Laboratory (USFWS)

The US Fish and Wildlife Service Forensics Laboratory, located in Ashland, Oregon, is widely recognized as the world's first and only full-service forensic lab dedicated exclusively to wildlife crime. Established in 1989, the lab

operates as a hub for forensic expertise and supports both national and international investigations.

The USFWS laboratory offers an extensive range of services, including DNA analysis, species identification, firearm and projectile examination, toxicology, pathology, and trace evidence analysis. It has played a critical role in several high-profile cases involving illegal ivory, rhino horn, exotic bird trafficking, and reptile smuggling¹⁷

Apart from investigative support, the lab conducts outreach and training programs for international enforcement officials, helping to establish wildlife forensic units in countries where such facilities are lacking. The lab also maintains one of the largest collections of wildlife reference specimens, enabling accurate identification of processed or obscure wildlife products. With its global remit under CITES and its affiliation with INTERPOL, the USFWS lab serves as a model of excellence for how forensic science can underpin wildlife protection.

4. NOAA Fisheries Forensics Laboratory

The National Oceanic and Atmospheric Administration (NOAA) operates a specialized forensic laboratory that focuses on marine species, including fish, marine mammals, turtles, and invertebrates. The NOAA Fisheries Forensics Laboratory supports the investigation of crimes related to Illegal, Unreported, and Unregulated (IUU) fishing, which is a major driver of biodiversity loss and economic disparity in coastal communities.

The laboratory utilizes DNA barcoding, mitochondrial analysis, and stable isotope profiling to determine species identity and origin, especially in processed seafood products that cannot be identified morphologically. From 2020 to 2022, NOAA's lab handled over 1,500 evidence items across more than 145 forensic investigations.¹⁸

NOAA's forensic work is critical in distinguishing legally sourced marine products from those harvested in protected areas or using banned

methods. This helps uphold international agreements such as the Port State Measures Agreement and ensures compliance with domestic laws like the Magnuson-Stevens Fishery Conservation and Management Act. The lab also supports consumer protection and sustainability certifications by identifying cases of seafood fraud and species substitution.

5. Society for Wildlife Forensic Science (SWFS)

The Society for Wildlife Forensic Science (SWFS) is an international professional organization founded to promote high standards, collaboration, and ethical practices among wildlife forensic practitioners. Unlike enforcement or operational agencies, SWFS plays a vital role in shaping the scientific foundation of the discipline.

SWFS offers a range of services, including individual certification programs, laboratory proficiency testing, and peer-reviewed guidance documents. It also maintains a strict code of ethics and promotes the use of validated methods through its Standards and Accreditation Committee. These efforts ensure that forensic results are reliable and legally defensible¹⁹

Every two years, SWFS hosts an international conference that brings together experts from around the world to discuss emerging issues, share research, and foster collaboration. The society also facilitates training workshops, online forums, and publications that help bridge the gap between scientific innovation and practical application in wildlife law enforcement.

6. TRAFFIC

TRAFFIC is a global conservation organization that monitors wildlife trade to ensure it is legal, sustainable, and traceable. Established in 1976 as a strategic alliance between the World Wide Fund for Nature (WWF) and the International Union for Conservation of Nature (IUCN), TRAFFIC operates in over 30 countries and collaborates with a wide array of stakeholders.

TRAFFIC contributes to wildlife forensic science

by gathering intelligence on trade routes, identifying market trends, and developing tools for species identification. The organization has produced several key publications and databases that guide enforcement agencies in identifying illegal wildlife products, including timber, ivory, pangolin scales, and marine species²⁰.

In addition to fieldwork, TRAFFIC is involved in capacity building, offering training on forensic methods, legal frameworks, and customs procedures. It works closely with CITES and INTERPOL to align trade monitoring with forensic practices, ensuring that science supports both conservation and law enforcement goals.

7. Netherlands Forensic Institute (NFI)

The Netherlands Forensic Institute (NFI) is a prominent European forensic agency that offers expert services in wildlife crime investigations. As part of the Dutch Ministry of Justice and Security, NFI provides advanced forensic support, including DNA analysis, isotope profiling, and digital forensics. In the context of wildlife crime, NFI assists in identifying species from animal remains, verifying origin claims, and uncovering links between suspects and illegal trade networks. The institute also supports the development of international wildlife forensic laboratories by providing training, equipment recommendations, and technical guidance²¹.

NFI's participation in European Union projects and collaboration with INTERPOL have helped harmonize forensic standards across borders. By contributing to both policy development and scientific research, NFI plays a crucial role in the institutionalization of wildlife forensics within the broader criminal justice system.

8. African Wildlife Forensics Network (AWFN)

The African Wildlife Forensics Network (AWFN) is a continent-wide initiative aimed at building forensic capacity in regions severely affected by wildlife trafficking. Africa, home to many of the world's most targeted species such as elephants, rhinos, and pangolins, has traditionally lacked sufficient forensic

infrastructure to tackle wildlife crime effectively.

AWFN focuses on training first responders, forensic technicians, and enforcement officers. It promotes best practices through standardized crime scene protocols, such as the widely adopted Wildlife Crime Scene Guide. This guide has been instrumental in improving evidence collection, handling, and documentation across diverse African contexts²².

In addition to field training, AWFN supports the creation and operation of regional wildlife forensic laboratories. It also facilitates cross-border collaboration by hosting regional workshops and establishing data-sharing frameworks. AWFN's work ensures that countries across Africa are equipped with the tools and knowledge necessary to conduct forensic investigations and prosecute successful prosecutions.

❖ Conclusion

Owing to the evolving landscape of wildlife crime enforcement in India. There are several key learning observations essential for enhancing the effectiveness of wildlife law enforcement like the Integration of Forensic Science in Enforcement, the pivotal role of forensic science in wildlife crime investigations and how DNA analysis, ballistic forensics, and digital forensics can provide irrefutable evidence, thereby strengthening prosecution efforts and enhancing conviction rates. An effective Multi-Agency Collaboration wildlife enforcement necessitates collaboration among various agencies, including the Forest Department, Police, Customs, and Border Security Forces. It is important that there are coordinated efforts and information sharing to combat wildlife crime effectively.

Capacity Building and Training is another area that we have to make concrete developments, there is an urgent need for specialized training programs to equip enforcement personnel with the necessary skills and knowledge, ensure initiatives like the Training Needs Assessment

(TNA) workshops organized by TRAFFIC India, which aim to assess and address the training gaps among enforcement agencies are implemented effectively.

The Legal Framework and Policy Support such as the Wildlife Protection Act, 1972, and their role in wildlife crime enforcement are in place but it necessitates for continuous policy updates to address emerging challenges in wildlife protection. And most importantly the Technological Advancements, i.e., the adoption of modern technologies, including cyber surveillance and data analytics, in tracking and preventing illegal wildlife trade. It underscores the importance of staying abreast of technological advancements to enhance enforcement capabilities. Finally, these are the several strategic next steps recommended to further strengthen wildlife law enforcement in India

- **Establishment of Specialized Wildlife Forensic Laboratories:** To support the growing need for forensic evidence in wildlife crime investigations, there is a need to establish and equip specialized laboratories across the country. These labs should be staffed with trained personnel proficient in various forensic techniques.
- **Development of Standard Operating Procedures (SOPs):** Creating and implementing SOPs for wildlife crime investigations can ensure consistency and efficiency. These procedures should encompass evidence collection, chain of custody protocols, and guidelines for forensic analysis.
- **Enhanced Inter-Agency Coordination:** Formalizing inter-agency coordination through Memoranda of Understanding (MoUs) can facilitate better information sharing and joint operations. Regular meetings and joint training sessions can further strengthen collaborative efforts.
- **Public Awareness Campaigns:** Launching nationwide campaigns to raise awareness about the consequences of wildlife crime can

deter potential offenders. Engaging communities in conservation efforts can also foster a sense of responsibility towards wildlife protection.

Monitoring and Evaluation Mechanisms: Implementing robust monitoring and evaluation systems can assess the effectiveness of enforcement strategies. Regular audits and feedback mechanisms can help in identifying areas for improvement and by focusing on forensic integration, multi-agency collaboration, capacity building, legal support, and technological adoption, India can enhance its efforts to combat wildlife crime and ensure the protection of its rich biodiversity.

The integration of modern forensic techniques in wildlife conservation represents a transformative shift in how we approach biodiversity protection. By offering scientific credibility, traceability, and precision, wildlife forensics strengthens enforcement and deters crime. While legal frameworks like the Wildlife Protection Act provide a foundation, ongoing reforms and technological investments are essential to harness the full potential of forensic science in preserving the planet's natural heritage. The intersection of forensic science and wildlife law enforcement represents a critical frontier in the fight against biodiversity loss and environmental crime in India. This study underscores the transformative role those forensic methodologies ranging from DNA barcoding and toxicology to geospatial analysis and trace evidence techniques—play in enhancing the accuracy, efficiency, and credibility of wildlife crime investigations. India, with its vast and biologically rich ecosystems, faces unique conservation challenges exacerbated by illegal poaching, trafficking, habitat degradation, and insufficient deterrents. Traditional enforcement approaches, though vital, have often struggled to meet the evidentiary demands required for successful prosecution in wildlife cases. As demonstrated through case analyses and institutional developments, forensic science fills this critical gap by enabling identification of species from

seized derivatives, pinpointing the origin of illegal materials, linking suspects to crime scenes, and providing courts with robust scientific evidence.

However, the integration of forensics into wildlife crime investigation remains uneven. This research highlights systemic limitations such as lack of infrastructure, insufficient training among enforcement personnel, and inadequate inter-agency coordination. Additionally, while the Wildlife Protection Act, 1972 provides a solid legislative foundation, it must evolve further to explicitly accommodate scientific advancements and facilitate admissibility and standardization of forensic evidence in judicial proceedings.

To accelerate wildlife crime investigations effectively, India must prioritize investment in regional forensic laboratories, build capacity among forest and police departments, foster interdisciplinary research, and strengthen legal frameworks to support science-based enforcement. Collaborative efforts between government bodies, scientific institutions, and international conservation networks are imperative to keep pace with increasingly sophisticated wildlife crimes.

As India moves toward a more science-driven and holistic model of conservation enforcement, forensic science must not be viewed as a supplementary tool, but rather as a central pillar in the country's strategy to protect its ecological heritage. The acceleration of wildlife crime investigations through forensics is not merely a scientific pursuit, it is a moral and ecological imperative.

ENDNOTES

1 Wyatt, T. (2013). *Wildlife Trafficking: A Deconstruction of the Crime, the Victims and the Offenders*. Palgrave Macmillan.

2 TRAFFIC (2020). *Pangolins in the Global Illegal Wildlife Trade*. www.traffic.org

3 INTERPOL & UNEP (2020). *Strategic Report: Environment, Peace and Security – A Convergence of Threats*.

4 Phelps, J., Biggs, D., & Webb, E.L. (2016). Tools and terms for understanding illegal wildlife trade. *Frontiers in Ecology and the Environment*.

5 Interpol (2021). *Wildlife Crime Scene Investigation Manual*. Lyon: Interpol Environmental Crime Programme.

6 EIA (Environmental Investigation Agency). (2022). *Routes of Illegal Wildlife Trade: Mapping Global Crime Chains*.

7 Cruz, A. et al. (2020). "Comparative Approaches in Forensic Science: Wildlife vs. Human Criminal Investigations." *Forensic Ecology Journal*, 12(3), pp. 45-59.

8 WWF India (2023). *Field Guide for Wildlife Crime Scene Management*.

9 Sharma, M. (2019). "Challenges in Forensic Chain of Custody in Remote Wildlife Crime Scenes." *Indian Journal of Environmental Law*, 7(2), pp. 22-30.

10 Rosa, I. L., Alves, R. R. N., Bonifácio, K. M., Mourão, J. S., Osório, F. M., Oliveira, T. P. R., & Nottingham, M. C. (2011). Fisheries and trade of seahorses in Brazil: historical perspective, current trends, and future directions. *Biodiversity and Conservation*, 20(9), 1951-1971.

11 Dias, T. L. P., Rosa, I. L., & Feitosa, C. V. (2011). The trade of ornamental mollusks on the beaches of Natal City, northeastern Brazil. *Brazilian Journal of Biology*, 71(1), 35-42.

12 Tobe, S. S., Kitchener, A. C., & Linacre, A. (2011). Reconstructing the origin of deer poaching using STR typing of human DNA recovered from the deer. *Forensic Science International: Genetics Supplement Series*, 3(1), e445- e446.

13 *Wildlife Crime: A Guide to the Use of Forensic and Specialist Techniques in the Investigation of Wildlife Crime*, ch. 5 (Partnership for Action Against Wildlife Crime ed., 2d ed. 2014).

14 *Wildlife Crime: A Guide to the Use of Forensic and Specialist Techniques in the Investigation of Wildlife Crime*, Ch. 2.5.1 (Partnership for Action Against Wildlife Crime ed., 2d ed. 2014)

15 TRACE Wildlife Forensics Network.

<https://www.tracenet.org>

16 United Nations Office on Drugs and Crime -
<https://www.unodc.org/unodc/en/environment/climate-change.html>

17 US Fish and Wildlife Service Forensics Laboratory.
<https://www.fws.gov/law-enforcement/national-forensics-laboratory>

18 NOAA Fisheries Forensics Lab.
<https://www.fisheries.noaa.gov>

19 Society for Wildlife Forensic Science.
<https://www.wildlifeforensicscience.org>

20 TRAFFIC. <https://www.traffic.org>

21 Netherlands Forensic Institute.
<https://www.forensicinstitute.nl>

22 African Wildlife Forensics Network.
<https://africanwildlifeforensics.org>

