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Forensic Wildlife: A Review

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Abstract

Wildlife crime, defined as the illegal capture, disturbance, ownership, exchange, or movement of animals and/or their derivatives, is a rising international problem that poses a threat to many species' survival. The 'crime scene' in such investigations can range from an animal carcass to terrain with topography as diverse as woodland or desert, as well as a variety of natural and man-made structures. The location of a wildlife crime scene is frequently remote, with insufficient facilities for thorough investigation and evidence collecting. These characteristics may pose particular issues in poorer sections of the world and countries suffering societal turmoil. Working at a wildlife crime scene necessitates the use of tools, investigation procedures, and scientific technologies that are all suited for the situation and the best available. A combination of portable and easy-to-use laboratory equipment, as well as current data gathering and information transmission systems, is likely to be required for effective inquiry in the field. It is critical to use an interdisciplinary approach. These tactics can be used to combat wildlife crimes and punish those involved in the illegal trafficking of animals, flora, and fauna, as well as their products. Footprint analysis, morphological and anatomical studies, microscopic inspections of bodily components, and molecular biology techniques such as serological, mitochondrial DNA, rRNA, and protein analysis are among these techniques. The well-documented methodology and techniques, as well as their disadvantages and advantages, have been thoroughly examined in this review, and will undoubtedly aid the court of law and scientists working in this field to reduce wildlife crime rates through scientific investigations.

Keywords: Wildlife crime, Illegal trade, Species determination, Sex identification, Molecular marker

Introduction

Wildlife crime encompasses illicit wildlife trafficking, ownership of wildlife animals, plants, and their products, as well as other violations of national and international law. It can also be defined as the unauthorized capture, ownership, trading, or movement of animals, plants, or their derivatives in violation of international, regional, or national law. Some also include cruelty to wild animals, both free-living and in captive, as well as persecution. Illegal wildlife flora and fauna trading is currently taking place all throughout the country. International trade poses a serious threat to the world's population, with at least a 50 percent reduction anticipated in the last 47 years. India's legal and policy framework for regulating and restricting wildlife trading is strong. In the current Indian environment, however, strong policies and implementation are critical.[1] After narcotics and guns, wildlife items are the third most illegally traded item. Wildlife crime is on the rise, and the

scope of the problem is unknown. Illegal trade in elephant ivory, wildlife animal skin, sport, food, and clothing are the leading cause of exploitation of wildlife natural resources. More than 60 to 70 percent of the world's population relies on herbal medication for their health needs.[2] The Tibetan Antelope (Pantholops hodgsonii) has been reclassified as Near Threatened from Endangered. Commercial poaching for the shahtoosh, which is used to produce shawls, is the main cause. The Bornean Yellow Muntjac (Muntiacusa therodes) is on the verge of extinction. Hunting for meat, skins, and traditional treatments are the main dangers. In 2016, the Grey Parrot (Psittacus erithacus) was upgraded from Vulnerable to Endangered on the IUCN Red List.[3,4]

Poachers are increasingly sophisticated tactics financed in many cases by covert or corrupt organisations, and countries facing what could be seen as a war on their environments often lack the manpower in terms of conservation officers, rangers, or law enforcement personnel to act as a deterrent or to handle the often overwhelming need.[5] Furthermore, poor countries face a severe lack of funding for military operations. There is frequently a lack of understanding, if not outright ignorance, of what is required in terms of investigative procedures. Even in countries with sufficient financial, personnel, and regulatory assistance, there is frequently a lack of experience and understanding of how to properly evaluate, investigate, document, and present these crimes in court.[6,7]

The illegal wildlife trade in mammals, birds, insects, and reptiles is well-connected all over the world, and thousands of wild animals, birds, insects, and fish are sold every year. In India, projects to protect wild animals such as sea turtles, crocodiles, hangul (red deer), tigers, elephants, and one-horned rhinos have been launched. The horns of one-horned rhinos are poached. The Ministry of Environment and Forests recently developed the Indian (One Horn) Rhino Vision 2020.[8] The goal of this initiative is to increase the number of participants by 2020. Seahorses and pipefish are illegally traded in Tamil Nadu, Kerala, Maharashtra, and Karnataka, India. The usage of it in anti-aging drugs, asthma, high cholesterol, goitre, kidney problems, skin ailments, and infertility is the main reason for exploitation.[9] Footprints analysis at crime scenes, morphological studies of the species, microscopic investigations of body parts, anatomical studies, and serological procedures are all diagnostic markers for species identification in wildlife forensics around the world. Hair, lengthy bones, species-specific tooth morphology, and other traits are used to make this determination. Cooked and dried meats, dried shark fins, egg shells, animal hairs, bone, ivory, rhinoceros' horns, turtle shell, feathers, and fish scales are among the evidences used to identify species in wildlife forensics.[10,11]

Crime Scene Investigation, Collection, And Preservation of The Sample

The primary goal of a wildlife crime scene inspection is to identify the species and cause of death, i.e., to connect the suspected wildlife criminals, victim, and crime scene. The essential precautions are to demarcate the search area, avoid congestion, put on sterile gloves before collecting samples, create a crime map, preserve, package, and forward the evidence. This section focuses on the measures that should be followed during the collecting of samples before they are sent to a forensic laboratory.[12]

With the advancement of DNA analysis technology, there is a significant benefit for wildlife inquiry. The identification of biological evidences for determining the species, gender, individual identity of samples, population, molecular taxonomy, and animal relationship or relatedness is a major challenge for wildlife DNA forensics. Because DNA evidences are often contaminated and degraded in the environment, it is critical to be cautious while sampling biological evidences.[13] As a result, it's best to gather samples from a crime scene as quickly as feasible. During sampling, careful work is required so that things can be properly documented, sized, packed, and kept for inspection at wildlife laboratories. Samples should be appropriately labelled with digits or alphabets, and their descriptions should be included in the forwarding notes, along with a crime scene sketch that shows where the samples were obtained. Samples must be appropriately packed and sealed. In addition, a sample of the seal should be included in the sending message. To verify that no tampering has occurred throughout the transit of items, maintaining chain of custody is a vital aspect of crime investigation.[14,15]

Contamination Precaution

Contamination is the most critical concern associated with the handling of biological DNA samples. During the collecting and transfer of evidence, there is always a substantial potential of DNA contamination. As a result, precautions must be taken to avoid contamination during the collection and preservation of DNA evidence.

The most important Pollution in DNA evidence occurs when other biological sources are mixed in with relevant DNA evidence, or when surface contamination comes into contact with the sample, or when faulty collection and preservation result in a significant danger of biological activity destroying the DNA authenticity.[16] To avoid and limit DNA contamination, the following principles should be followed.

Secure the area and restrict access to only the most important people. Always use sterilized, high-quality gloves and replace them frequently. As much as feasible, handle the evidence with care. Avoid touching any areas where there is a chance of finding DNA evidence. Before or after sampling, use disposable or single-use objects, as well as clean sterilized non-disposable things. It's best not to tread on or over evidence. As much as possible, avoid speaking, sneezing, or coughing near the crime scene or over evidence. Individual scientific evidence should always be recorded and stored in sealed envelopes or containers with suitable documentation. Before packaging, thoroughly air dry the evidence. For any forensic biological evidence, it is recommended that you avoid using plastic packaging for the inner or outer covering and instead use paper bags, envelopes, cartons, or other comparable materials. To avoid cross contamination, each piece of evidence was packed separately. If you are hurt, get out of there. A sufficient care is made to avoid direct bodily and mouth contact with investigation tools that may have come into contact with contaminated surfaces. Avoid eating, drinking, chewing gum, smoking, or using tobacco around a crime scene as much as possible.[17,18]

Sampling

When sampling biological material for genetic analysis in a wildlife crime investigation, the same chain of custody, labelling, transport, and storage processes and protocols must be followed as with other samples. All collection material and tools must be free of "external" DNA from the collector or other potential sources of contamination during sampling. It is suggested that you use sealed and disposable tools.

Sampling should be done by qualified and trained persons in general. To avoid cross-contamination, personal protective equipment (PPE) must be used, and gloves should be replaced between sampling of various materials and/or samples.[53]

To avoid material degradation and contamination, storage and transportation are critical, and various materials require different circumstances. If you have any doubts, you should always contact the laboratory that performed the genetic analysis for more information.

A large range of commercial kits for collecting genetic material is now accessible.[54]

In wildlife crime situations, using these kits is highly advised because it decreases the danger of inappropriate sample collection and processing. All directions from the manufacturer regarding usage, storage, and shipment mode must be followed.

- ***Soft Bodily Tissue:*** Any soft bodily tissue (organs, muscles, etc.) from a carcass can be retrieved for genetic study. Except for samples of very degraded remains, a minimal amount (5 gram) is usually sufficient. Tissues should be stored at -20°C in an airtight, shatter-proof container. Samples should be sent in a cooler with ice packs by express postal service.[55]
- ***Bone, Teeth, Eggshell:*** Bones, teeth, antlers, and eggshells should not be cleaned or bleached before being processed. DNA extraction works best with large molar teeth or large bones (humerus, femur). These items can be stored and sent at room temperature.[56]
- ***Hair/ Feather:*** Hair/Feathers: Gloved hands remove a quantity of hairs and feathers from the body. Do not cut the hairs with scissors or other tools because the best effects are obtained by cutting the hair roots, adhering to the sample. Hairs and feathers must both be removed. Kept and sent at room temperature in a paper envelope or bag. Putting these together, Degradation is increased by placing samples in a tight-sealing plastic container. Mold has infected the samples, rendering them unusable for genetic study.[57]
- ***Blood:*** Blood can be obtained from very fresh carcasses using sterile veterinary equipment and preserved in an anticoagulant tube. Blood tubes should be kept at a temperature of +4°C or less. Avoid thawing and refreezing multiple times since DNA deterioration will occur. Samples should be sent in a cooler with ice packs by express mail. However, in the vast majority of wildlife crime situations, taking blood samples on the spot will be impossible. Blood may be taken during necropsy in such circumstances. Wet blood can be transferred to swabs or specific filter paper and stored at room temperature in a swab tube or a paper envelope. Dried blood on the carcass or any other

object of interest can be collected with a slightly dampened swab and dried in a swab tube or paper envelope. Blood stains on ice or snow can be collected in a tightly sealed container with the original material. The samples should be kept frozen at all times. Avoid thawing and refreezing multiple times since DNA deterioration will occur. Samples should be sent in a cooler with ice packs by express mail.[58,59]

- ***Saliva:*** Swabs can be used to sample saliva on any object or a wound of an animal allegedly killed by a predator. The swab should be inserted in the swab tube after air drying at room temperature and stored and delivered at room temperature.[60]
- ***Urine:*** Fresh urine should be collected in a tight-sealing container (minimum 50ml) and frozen as soon as feasible at -20°C. Samples should be sent in a cooler with ice packs by express mail. Dried urine on any object can be collected with a slightly moistened swab and dried at room temperature in a swab tube or paper envelope. Urine on snow or ice should be collected in the same way as blood stains are collected on these surfaces.[61]
- ***Feaces:*** Wet faeces should be sampled as soon as possible and frozen at -20°C in a tight-sealing, shatter-proof container. Dry faeces should be stored and sent at room temperature in a paper bag or a breathable container.[62]

Wildlife Crime Analysis And Technique Used

The identification of confiscated materials and protected species must be sent to forensic laboratories that deal with wildlife crimes or research institutions that deal with wildlife. In forensic laboratories, several unique traits of species or confiscated materials are used to identify wildlife species. Footprint analysis at crime scenes, morphological research of the species, serological approach, and molecular biology techniques are currently used for animal species identification.[19]

Analysis by Footprints

Footprints of wildlife species are crucial evidence in species forensic investigation. Footprints are the imprints of an animal's foot on surfaces where it walks or in captivity. The pattern of the footprints and their size are used to determine the species type and age. The main issue with using footprint imprints to identify species is that they are typically unnoticeable on hard surfaces, and these footprint locations are frequently contaminated by the presence of other animals.[20]

Morphological Analysis

The easiest form of wildlife forensic procedure in the identification process of evidences and the least expensive forensic analysis is morphological or physical characteristics. Important hints based on external appearance are provided in the identification of species based on morphological characteristics of wildlife flora and fauna. Different species have different physical characteristics such as skin coat colour, pattern of coloration, eyes, pinna, tails, ivory, and so on. Ivory is a type of dentine that has a distinct pattern known as schreger that is illegally trafficked from Asian or African elephants.[21] It also features an angled pattern that serves as a means of distinguishing it from other species. When a whole skin or skeleton is given as evidence, morphological, anatomical, and microscopic study can aid in species identification. In morphology-based identification, experience and a database of known or reference samples become extremely important. When animal skin evidence is seized, for example, hair analysis and comparison with a reference sample are critical in determining the species of origin.[22] This type of evidence is examined and compared to existing reference materials such as taxonomic keys and species monographs. The lack of availability of the whole animal or its intact components preserved as such is a fundamental challenge with morphological identifications, and morphological analysis is again limited to the level of genus or its higher taxonomic level.[23]

Examination by Microscope

The morphology, elemental analysis, and cuticular scale pattern of the hair are all included. Hair is an important feature that can be utilised to identify a species. The identification of animals based on hair evidence can be done using a scanning electron microscope. Scanning electron microscopy gives a larger magnification range and linked Energy Dispersive Spectra, allowing elemental analyses such as sodium, potassium, calcium, and sulphur to be used to identify geographical regions. For mammalian species, hair scale patterns of various species have been documented in Australia and Europe. The fundamental drawback of microscopic techniques is that they require well-preserved samples for microscopic inspection.[24]

Serological Techniques

Serological approaches, like the lock and key paradigm, are based on the interaction between antibodies and their corresponding antigen. Species-specific antibodies are employed to identify the biological evidence's species of origin. The lack of species-specific antibodies in our laboratory is one of the most worrying issues with serological techniques. Antibody cross-reactions in non-target species have also been shown to give favorable outcomes. As a result, in forensic analysis, it is only used as a presumptive test.[25]

Infra Red Techniques

Spectroscopies such as mid-infrared, near-infrared, and Raman, in combination with chemometric approaches, have been shown to be particularly effective in distinguishing species and in identifying the geographical origins of herbal remedies. Because of its great dependability, low cost, and ease of examination of biological evidence such as soil, food, and beverages, NIR spectroscopy is widely used. Wildlife can be identified using near-infrared spectroscopy. Nuclear DNA, mtDNA, and DNA fingerprinting are among the molecular technologies used to determine the origin of species, which aids in the enforcement of wildlife protection laws. Geographic origin has also been determined using genetic approaches. The provenance has also been determined using assignment tests and microsatellites.[26,27]

Radio Isotrope Tracer Technique

In wildlife forensics, this approach is used to discover trace components in the evidential remnants. Radioisotopes are more plentiful in different places, and the presence of such radioisotopes indicates their most likely origin based on isotope abundance maps. Essential and trace elements are the two categories of elements assimilated into the body. Aluminum, arsenic, beryllium, cadmium, chromium, molybdenum, nickel, lead, and tin are examples of non-essential elements. Increased levels of trace metals in the body can be caused by intake and inhalation of trace metals from the diet and environment. As a result, radioisotope tracer techniques are being used in the discovery of species origin. Mt-DNA markers have also been used to determine a person's geographic origin. In such instances, identification based on DNA analysis becomes crucial in wildlife forensics when physical traits of species are lost. Forensic mt-DNA markers like as 16S rRNA, 12S rRNA, Cytochromeb, and Cytochrome Oxidase are employed in wildlife for identification, as well as phylogenetic study. Interspecific variation can be seen in these mtDNA-based markers. Interspecific variation can be seen in these mtDNA-based markers. The genetic marker that is available for many species and subspecies from various geographical ranges is useful in wildlife forensics, but much work has to be done in the present and near future to build a marker of DNA sequence repository of wildlife flora and fauna.[28,29,30]

Laboratory Investigation in Wildlife Crime

General Pathalogical Investigation

In any situation involving visible dead wildlife, veterinary pathology tests are essential. The pathologist can determine not only the cause of death, including the manner and reason for death, but also any underlying pathology and any cause of illness. In addition, forensic pathologists are professionals who may analyse and evaluate the need for additional investigations based on pathological results. As a result, in suspected illegal homicides, a detailed and thorough pathologic investigation at a recognised laboratory is critical! Remember that corpses are more than just dead bodies; they're also bundles containing valuable knowledge and prospects for the future.[31,32]

Species Determination

While determining unique species in mammals such as the wolf, bear, and lynx is simple, correctly identifying birds of prey by physical traits can be difficult. In some species, such as harriers, this is especially true for young individuals aged three years or less. Although various field guides are available to help with bird and other animal identification, the examiner may consult biologists, particularly ornithologists, if in doubt. If you don't have a working relationship with these experts yet, any natural history museum or a university's biology department can help you find one. If morphological criteria, such as the corpse being badly decomposed, do not allow for a correct species classification, a genetic examination of any tissue from the carcass will provide the necessary information.[33]

Age Determination

In a rare circumstance, determining the age of an individual victim may be simple if the person is "known." This could be the situation if the animal was collected and marked during scientific research and then released as part of a reintroduction campaign. The age of an individual is usually determined

over the course of these projects/studies, therefore contacting the project directors is beneficial. In all other circumstances, determining one's age might be difficult, and experts may be consulted. Various physical traits are utilized depending on the species, just as they are for species identification:[34]

Individual size and weight; pelage/plumage colour; ossification of various bones and bone sutures; ossification of various chondral tissues; dimension of bony structures; dentition, eruption, and tooth wear (in mammals). The dental characteristics of large carnivores, particularly the incisors, show regular changes with age and so allow assigning an individual to at least different age categories, such as 1 year, 1–2 years, 3–6 years, 7–9 years, 10–13 years, and 14 years in lynx. Microscopic analysis of the so-called cementum annuli rings of the incisors, canines, or premolar teeth can yield very precise age determination findings in wolves, bears, and lynx, but this approach is only used by a few specialised laboratories. With the exception of some species of birds of prey, whose plumage displays distinct coloration until they are about three years old, age determination in birds is often limited to simply classifying them as juvenile or adult due to the lack of distinct morphological characteristics that allow for a more precise age classification. It's important to remember that genetic testing won't help you figure out your age.[35,36]

Determination of Post Morteum Interval

Many chemical and physical processes begin in a carcass shortly after death, leading to decomposition and, in most cases, eventual skeletisation if left undisturbed. The autolysis and, in rare cases, the putrification processes are both involved in decomposition. Mummification, or the drying of the corpse, may occur in specific circumstances. During necropsy, the pathologist may be able to ascertain at least a reasonable estimate of the time since the individual's death based on the sequence of events. All of these processes, however, are highly varied and are influenced by a variety of intrinsic and extrinsic factors, such as the animal's species and size, ante-mortem activity, cause of death, and environmental conditions, among others. Enormous creatures, such as a bear with thick winter fur and large fat depots, cool more slowly than starving birds.[37] Postmortem cooling models have been established in human forensic sciences during the first few hours after death, however there is very limited data on different animal species, and human data cannot be easily generalised to each animal species. Scavenger activity and mummification after death might also be mistaken as stages of decomposition. As a result, determining the post-mortem interval simply based on the parameters listed above is not well established scientifically, and no practical field application exists. When analysing the findings, use caution! The pathologist must, however, carefully analyse and document the post-mortem alterations detected in a carcass. The intraocular pressure has recently been discovered to be a good predictor for brief (less than 12 hours) post-mortem intervals, and this method could have future promise if verified in a variety of animal species. Other strategies, such as differences in various body fluids properties, have failed to work in humans, let alone animals. Carcasses are frequently discovered later in the post-mortem period in animal forensic cases, rendering the methods indicated above worthless. In such circumstances, entomological examinations of the insects and various stages of larvae that occupy a carcass after death may yield useful information on the time since death.[38,39]

Pathalogical Finding Due to Electrocution

Birds that cut the electricity when perching on and, especially, lifting off from electrical lines are nearly exclusively electrocuted. Due to the low strength of current, electrical fences used to fence off a pasture, for example, will not harm ground-dwelling animals. From the contact point to the point of exit, electrical current normally takes the quickest path through the body. The current runs through the body's least resistant tissues, which include neurons, blood vessels, and moist tissues. Acute cardiac fibrillation, cardiopulmonary arrest, or brain injury are the most common causes of death.[40]

Pathological results can range from severe thermal burns to hardly visible local markings, especially when the tips of feathers were the only areas of contact.

Due to the current disturbing the neurological system, traumatic amputation of wings, legs, or digits may occur as a result of extreme muscular contractions. During necropsy, look for burnt feathers on the wings and wrists. However, because these might be difficult to tell apart from dirt, a dissecting microscope is suggested. Using an additional light source at 530 to 570 nm through a red filter, burnt feathers and skin can also be identified. Look for any discolorations on the feet. Additionally, inspect the whole skin of the carcass for current entry and exit holes. Only minor charring may be visible in these holes.[41,42]

Internal damage might include serious thermal burns if the current is present in the body for an extended length of time. Muscles may show signs of fatigue.

Cooked appearance, discoloration, and visceral ruptures are possible. Internal damage, on the other hand, is essentially non-existent in several situations when the electrocution was quite brief.

In the skin, histopathology may reveal coagulation necrosis and intra-epidermal separation.[43]

Pathalogical Finding Due to Collision With Vechicles

Vehicles and trains may crash with a variety of mammals and birds. A frontal collision in a small species will result in various and severe traumatic lesions, largely blunt force, such as bone fractures, luxations, laceration, and ruptures of interior organs and tissues. There will be a lot of bleeding in different tissues. Due to projection of the animal, coup-contrecoupe effects caused by the quick acceleration/deceleration process in accidents, and other factors, injuries to body parts outside of the immediate impact location may occur. Collision victims frequently have several abrasions on their skin and dirt embedded in their fur.[44]

When large crash victims with vast muscles and/or thick layers of fat, such as bears, are hit in the peripheral region, only minor pathological alterations such as bleeding in the skin and musculature may occur. Although there may be no visible wounds on the outside, look for vehicle paint chips. However, due to the pressures involved in crashes, death can result from the rupture of internal organs and subsequent internal haemorrhage. Larger or faster-moving vehicles can also kill flying birds by creating a downdraft, so there is no direct hit.[45,46]

Lung lacerations are a common occurrence in windmill victims.

Genetic Investigation

Human forensics has used DNA analysis, the molecules that carry genetic information, since the late 1980s. The linear shaped nuclear DNA found in the nucleus of a cell and the circular shaped mitochondrial DNA found in the cell's mitochondria are found in practically every cell of an animal. Mature red blood cells are a significant exception to DNA-carrying cells. Because linear shaped nuclear DNA is very sensitive to deterioration in disintegrating tissue, mitochondrial DNA is frequently better suited for forensic reasons. Furthermore, mitochondrial DNA can be found in hundreds of copies in a single cell, compared to only two copies in nuclear DNA. While nuclear DNA is transmitted down by both parents, making it more susceptible to recombination, mitochondrial DNA is only carried down through the maternal line, making it more stable. However, in each forensic case, the genetic lab will determine which DNA to utilize, as this will be determined by the question that the forensic genetic inquiry is addressing.[47,48]

Species Identification

Blood stains, traces of saliva, faces, feathers, and hairs (all materials that, with the exception of hairs and feathers, cannot be conclusively identified to a single species) are frequently used in wildlife crime investigations. Furthermore, because organic tissues deteriorate to the point where it is hard to identify the species from which they originate based on physical traits, genetic analyses may aid in the identification of various species. Most species and subspecies now have publicly accessible genetic reference databases, allowing examiners to compare the DNA profile of a sample in issue to the unique profiles of species in the databases.[49]

Population Origin

Animal or animal parts may be traced back to their source using genetic analysis. To do so, a reference database is required to match a sample's DNA profile to the known diverse DNA profiles of animals from different areas and/or populations. Because the various DNA profiles of the nine main populations in Europe are known, wolves can be assigned to the population and location from where they originated.[50]

Individual Identification

Reference DNA profiles of the unique individual are required for allocating, for example, a hair sample to a single individual or identifying an animal found dead individually. For this reason, it is advised that all individuals treated during conservation initiatives, such as those bred in captivity for release or animals taken for marking, be sampled for genetic analysis.[51]

Sex Determination and Sample Matching

Male and female mammals have different DNA sequences (for example, the XX chromosomes in female mammals vs the XY chromosomes in male mammals), genetic study can easily determine the individual's gender. Genetic studies can be performed to identify if two or more samples are

from the same person, such as whether blood spots on a car were from a found carcass, whether antlers match a certain individual, and other concerns.[52]

Discussion

The lack of species-specific antibodies in serological analysis, undetectable footprints and erosions by other animals in footprint analysis, the need for samples in well-preserved form in microscopic analysis, and the lack of taxonomic keys and wild animal monographs are all major limitations in wildlife forensics. In the current situation, wildlife conservation is critical in order to limit or prevent the illegal trade in wildlife flora and fauna. Poaching, encroachment into forest areas, and wildlife-related crimes must all be avoided. Wildlife forensics aids law enforcement agencies in prosecuting wildlife criminals and smugglers. Wildlife forensics in India is still underdeveloped, and animal officers are undertrained in applying forensic scientific approaches to wildlife crimes. Having a basic understanding of wildlife forensics will greatly improve their ability to handle wildlife-related offences. A single feature of a species, such as hair morphology, may be shared by closely related species. It is advisable to combine the results of more than one technique in the case of any doubt in species identification. Although molecular approaches can identify a species by themselves and are quite exact and specific, species-specific characteristic markers are not accessible for all species.

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