DNA analysis of wildlife is unquestionably providing valuable insights into ecology, evolution and conservation (Frankham *et al.*, 2009) but is the technique being used effectively for international wildlife law enforcement as a wildlife forensic tool? At the seventeenth meeting of the Conference of the Parties to CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) (CoP17) dedicated wildlife forensic events and discussion featured prominently in subjects as diverse as synthetic fabrication of rhinoceros horn to monitoring the trade in timber. With all this attention on the emerging discipline of wildlife forensics—which can be subject to divergent interpretations by the international community—it is important to evaluate the current landscape and challenges when applying wildlife forensics for various purposes.

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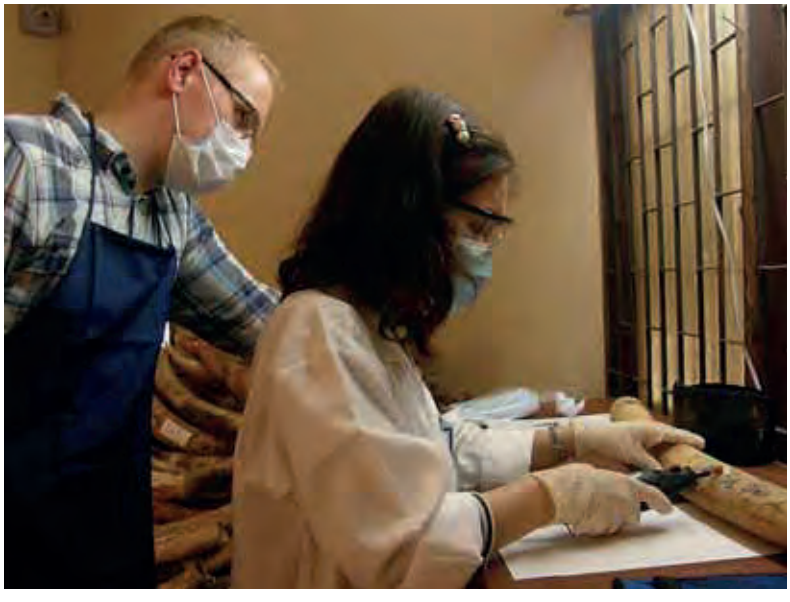
OUT OF SEQUENCE: is wildlife DNA forensics delivering as an illegal trade enforcement tool?

The discipline of wildlife forensics focuses on using scientific techniques to help address illegality in relation to national laws or international wildlife conventions. Although many different scientific techniques help address aspects of wildlife crime, DNA analysis is by far the most commonly used technique owing to its ability to resolve most of the important common questions; the generic accessibility of the technique through established academic or government laboratories, and the prior legal precedent for accepting DNA evidence in courts.

"Forensics" as defined, relates solely to the application of a scientific technique to a legal case. Commonly, scientists working in the wildlife field are generally applying this discipline in three different, but not mutually exclusive areas, either directly in casework; or indirectly in traceability and intelligence gathering.

"Casework" is the use of DNA analysis to address a specific question relating to a criminal investigation or "case". As this area of work is supporting, or refuting, a legal matter, it therefore requires the highest degree of assurance that any DNA analysis is fit for legal purpose and that the interpretation of any result is measured and fairly presented for the benefit of the court. Similar to human DNA forensics, wildlife DNA forensic evidence can result in a criminal conviction and a loss of liberty and therefore the process is not to be undertaken lightly or with pretence that wildlife crime requires less stringency in the production of data or scrutiny of those data.



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Wildlife DNA forensics as a casework tool commonly goes underreported in the media as the DNA analysis tends to be a component of a larger evidence base for a wildlife prosecution, which is often lost in media reporting and typically the time period between analysis and any judgement often means the laboratories undertaking the work are themselves unsure of the outcome and too busy to self promote, despite the benefits of quantifying the use and success of DNA testing in this field.

The most frequently used DNA test for casework addresses questions of the identification of a species when the normal morphological characters are absent. Only by first categorically identifying the species of a wildlife specimen can enforcement action based on the legal status of that species and/or its trade be initiated. As DNA analysis for protected species identification has been technically feasible for some time (e.g. Baker and Palumbi, 1996), it does not attract large amounts of research or international collaborative interest, despite a continued need for this, and when this does occur, it is often well intentioned but with limited utility. However, at a forensic rhinoceros DNA workshop, held in July 2016 in South Africa (TRAFFIC, 2016), where discussions were focused around testing the benefits of the individualization of rhinoceros, it was the absence of a standardized DNA species identification test for rhinoceros that was identified as the most immediate and useful casework requirement from an international perspective. Similarly, various research groups are working on methods to identify the geographical provenance of illegally traded species. Although this information is important, the most pressing enforcement tool from a casework perspective may simply be the ability to identify the species from the parts or derivatives in trade. The pangolin trade is a useful example of where the immediate casework requirement is a species DNA test to identify robustly all pangolin species from scales, something currently hampered by a lack of suitable and trustworthy reference DNA data. The rush to tackle more academically interesting research orientated projects such as pangolin geographical origin, often shows a disconnect between the immediate requirements of law enforcement and the well meaning direction of academic researchers.

"Intelligence" or information-gathering from DNA testing of wildlife products is the most commonly reported area of wildlife forensics as it can produce results in a manner and timeframe suitable for enforcement action, and media attention without any issues around the *sub judice* of reporting casework. The aim is to provide information to direct enforcement investigations or inform policy in relation to illegal trade of wildlife.

The most comprehensive system for gathering information on illegal wildlife trade is the geographical provenance DNA testing of African Elephant *Loxodonta africana* ivory developed by Professor Sam Wasser at the University of Washington (Wasser *et al.,* 2004). At the direction of CITES, ivory seizures greater than 500 kg are required to be geographically sourced (CoP16 Decision 16.83) and although other methods to establish this exist (Ziegler *et al.,* 2012), generally sub samples from large seizures are physically transferred to the USA, and the DNA tested to identify its likely African country of origin. As DNA data for this purpose are not intended for prosecutions, the data can be interrogated in a more general way to identify trends.

However, to be effective as an enforcement tool, intelligence about wildlife trade or illegality in the wildlife trade needs to be current to initiate a meaningful counter response or a subsequent criminal investigation. The testing of DNA to establish the provenance of African ivory has resulted in useful high profile research publications (e.g. Wasser *et al.,* 2007; Wasser *et al.,* 2015) and policy discussion, but perhaps future developments should centre around expanding the technical capacity to undertake this DNA testing in transit/consumer countries, therefore ensuring results are generated in a timescale suitable for interventions at the earliest opportunity to support enforcement and prosecution, as urged by CITES (Resolution Conf. 10.10 (Rev. CoP16)).

Similarly, the Rhino DNA Index System (or RhODIS) DNA database system (Harper *et al.,* 2013) used to individually identify Black and White Rhinoceroses *Diceros bicornis* and *Ceratotherium simum* in Africa also has a function in providing information on trade routes for rhinoceros horn, in addition to its core focus of providing evidence for national casework in South Africa linking seized rhinoceros horn with poached rhinoceros carcasses. Again, DNA samples from seizures in transit/consumer countries are requested, and urged by CITES (Doc. 54.2, CoP16), to be analysed in South Africa. However, the international transfer of rhinoceros horn samples back to South Africa for the RhODIS system to be used to its full potential has not been well co-ordinated to date, with considerable time lags experienced and delays in reporting, and also a lack of enforcement agencies identified to interrogate the data from an international perspective to justify the exercise meaningfully.

The third area for wildlife DNA forensics is the use of DNA testing for the "traceability" of illegality associated with wildlife or derived products, such as DNA registration schemes of wildlife or wildlife products. This area is probably the most underused but arguably the most useful, wildlife DNA forensics technique. The ability to demonstrate legal, and illegal, trade of wildlife products such as ivory, rhinoceros horn, Tiger derivatives or captive-bred animals using DNA tests to monitor or register large populations has generally been deemed too financially expensive to initiate. However, advances in DNA profiling technology now makes such DNA registration and monitoring schemes affordable and deliverable and therefore of great utility in addressing trade issues. Recent examples of this kind of system are the DNA registration scheme on trial by Thailand's Department of National Parks for domestic elephants, with the aim of ensuring wild elephants are not laundered into the legal trade for domestic elephants, and the DNA registration schemes being tested for captive Tigers in

◄▲ **Wildlife DNA forensic capacity building in Gabon** (top, left); **Malaysia's National Wildlife Forensic Laboratory developing Tiger identification techniques** (top, right).

◄ **Collaborating on ivory DNA identification in Thailand.**

both Malaysia and Thailand to prevent the laundering of Tigers or their parts into the illegal trade. Both of these projects were driven by enforcement needs identified by TRAFFIC (Nijman, 2014) and CITES (SC66 44.2) respectively. This needs-based approach is key to delivering tangible results from wildlife DNA forensics testing. The current approach however, seems to involve academic researchers developing, or being encouraged to develop new techniques (https://wildlifecrimetech.org/), with a greater emphasis needed to understand the intricacies and limitations of wildlife crime investigation and legal reporting.

In order to develop DNA testing into the wildlife forensic technique it should be, networks of like-minded individuals need to be created and should comprise: the non-governmental organizations (NGOs), enforcement officers and prosecutors identifying the drivers for developing new DNA tests, the academic researchers developing these new tools and technologies based on the needs, and the scientists tasked with undertaking forensic DNA testing ensuring the tests are run within their identified limits and reported without bias in a neutral evidential way. There are membership organizations such as the Society for Wildlife Forensic Science and International Society of Forensic Genetics with a remit to promote such networks. Historically these organizations predominantly comprised scientists from developed countries, but more concerted efforts have been made to include members from emerging laboratories in Africa and Asia in recent years.

As part of a joint initiative between the USAID-funded Wildlife TRAPS (Wildlife Trafficking, Response, Assessment and Priority Setting) project, implemented by TRAFFIC, and the UK Government-funded TRACE Wildlife Forensics Network organization, a process of engaging scientists in key developing countries from range, transit and consumer countries with an interest in this field has begun. The recent RhODIS Scientific Workshop funded by the USAID Wildlife TRAPS Project and WWF, in partnership with the University of Pretoria Veterinary Genetics Lab (VGL) and TRACE Wildlife Forensics Network in South Africa, epitomises this approach, bringing together key scientists and enforcement officers from across the world to identify fully the wildlife enforcement issues and challenges and develop a range of DNA testing outputs to address shortfalls in the current suite of tools. Only this needs-based, collaborative approach will fully develop the field of wildlife DNA forensics into an applied and useful enforcement tool to disrupt the illegal trade in wildlife products and prosecute those involved.

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Advances in DNA profiling technology allow for DNA registration schemes to be tested for captive Tigers.