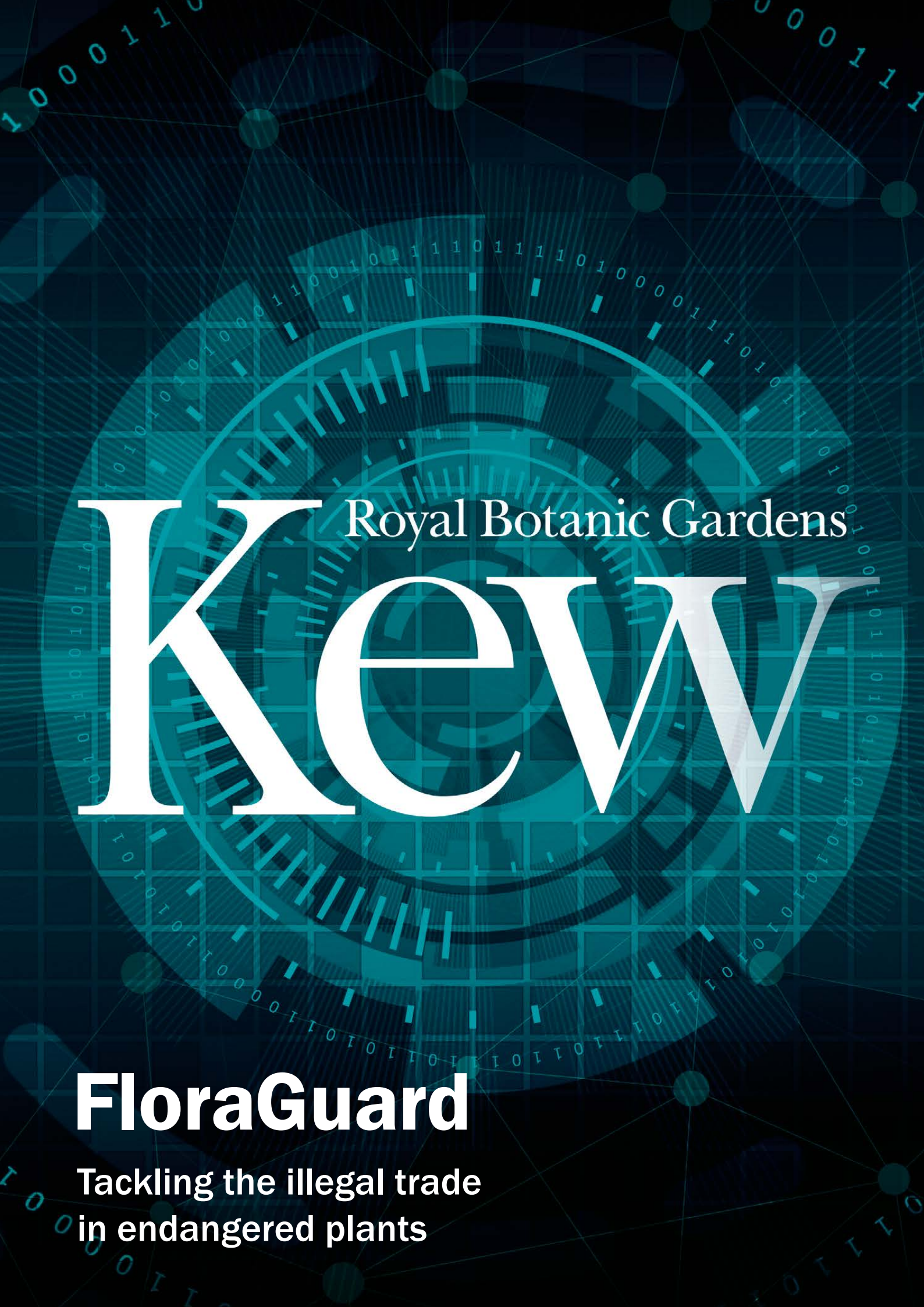


FloraGuard

Tackling the illegal trade in endangered plants

Foreword

The word poaching may not be readily associated with plants, yet illegal collection from the wild poses a direct threat to many of the world's most iconic plant species such as orchids, cacti and cycads.

In recent decades, the trade in illegal live specimens, along with other plant products, has spilled onto the internet, providing illegal traders with a means of reaching a global consumer base, while remaining cloaked in the anonymity and vast scale of cyberspace. Yet the adopting of online technology by wildlife traffickers also presents opportunities to map, understand and counteract this trade.

The recent global report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) identified that direct exploitation of organisms – in which illegal wildlife trade plays a central role – is one of the most impactful drivers of change in nature, second only to changes in land and sea use. Species exploitation is even more damaging to biodiversity than climate change. Safeguarding the natural world against this threat requires innovative approaches and effective collaborations. Led by the University of Southampton and partnered with UK Border Force and the Royal Botanic Gardens, Kew, the FloraGuard study took a new approach to meeting this challenge. The study's findings encompass insights into the criminological mindset of plant traffickers, the use of botanical expertise to identify suspicious online posts and the potential application of cutting-edge artificial intelligence techniques. This level of cross-disciplinarity illustrates the range of expertise involved in the project and the scope for further innovation that exists within the field of online trade enforcement.

Effectively countering illegal wildlife trade is of critical importance not only for the survival of those species at risk, but also for the message it delivers and the benefits to responsible trade. Measures to discourage the illegal online trade in plants enable genuine online sellers and consumers, whose enthusiasm for plants is cause for celebration, to trade with greater confidence and align with the environmentally sustainable use of natural resources. In many countries, such as Ecuador and Thailand, this trade brings important income to livelihoods and often enables the protection of the ecosystems where species are sourced.

I am confident that the FloraGuard project will help inspire new alliances between scientists, practitioners and businesses. Conservation science has a strong track record of applying new ideas within its practices, with the benefits of such a collaborative approach reflected in the pages of this report. Today, developing solutions based on cooperation and mutual understanding has never been so important, as we strive for a sustainable future in an increasingly connected world.

It is therefore my great pleasure to introduce FloraGuard, which illustrates the benefits of applying a multi-disciplinary mindset to tackle the illegal trade in wildlife.

Professor Alex Antonelli
Director of Science, Royal Botanic Gardens, Kew

Iroko tree being cut near Imbolo,
Democratic Republic of Congo

Contents

1. Project overview

1.1 Project partners

The University of Southampton is a global centre for excellence in research and education and a founding member of the Russell Group. The FloraGuard project has been developed with the Department of Sociology, Social Policy and Criminology and the Department of Electronics and Computer Science.

www.southampton.ac.uk/sociology

Border Force is a law enforcement command within the Home Office. As part of their duties, Border Force secures the UK border by carrying out customs controls for goods entering or leaving the UK. The Border Force CITES team, based at Heathrow but with a national remit, are highly regarded specialists in the protection of endangered species.

www.gov.uk/government/organisations/border-force

A world-leading botanic garden, Royal Botanic Gardens, Kew is the UK CITES Scientific Authority for flora. Kew's Conservation Policy team perform scientific research into plant groups affected by international trade, provide independent advice on CITES legislation, and work with enforcement authorities on the inspection, holding and disposal of detained or seized CITES material.

www.kew.org/

1.2 The FloraGuard team:

Principle researchers and team leaders:

Name	Title	FloraGuard role and specialisms
Dr Anita Lavorgna	Associate Professor in Criminology, University of Southampton	Principle Investigator – Criminology
Dr Stuart E. Middleton	Lecturer in Computer Science, Department of Electronics and Computer Science, University of Southampton	Co-Investigator – Computer Science (Natural Language Processing, Artificial Intelligence)
Guy Clarke MBE	Higher Officer, UK Border Force CITES team	Direction and guidance on issues of law enforcement
Dr Carly Cowell	Head of the UK CITES Scientific Authority for Flora, Royal Botanic Gardens, Kew	Direction and guidance on issues of conservation science
David Whitehead	Science Officer, CITES, Royal Botanic Gardens, Kew	Project support and research on issues of conservation science

Illegal Wildlife Trade Conference in London, 2018

1.3 Authors, key contributors and acknowledgements

This report was written and edited by Dr Anita Lavorgna, Dr Stuart E. Middleton, David Whitehead, Dr Carly Cowell and Michelle Payne.

FloraGuard is indebted to Dr Maurizio Sajeva and Dr Noleen Smyth, whose insights and ideas led to the genesis of the project.

We would also like to thank Catherine Rutherford for her important contributions to the preliminary stages of this research. Special thanks are also owed to the following researchers, whose key contributions at various stages of the project aided the development and execution of the study: Valentina Vaglica (Royal Botanic Gardens, Kew), Geoff Neumann (Computer Science, University of Southampton), Brian Pickering (Computer Science, University of Southampton) and Sara Redstone (Royal Botanic Gardens, Kew).

Advisory committee:

Royal Botanic Gardens, Kew; UK Border Force; INTERPOL Environmental Security Unit; Metropolitan Police; TRACE Wildlife Forensics Network; TRAFFIC; and Plantlife.

1.4 Research grant information

This work was supported by the Economic and Social Research Council [ES/R003254/1].

1.5 Summary

In 2020, protecting the world's biodiversity is high on the global agenda. Although international summits to strengthen environmental protections have been postponed due to the COVID-19 pandemic, the pandemic may only intensify debate and reframe calls for action when the world meets again. The illegal wildlife trade (IWT) is one of the many threats to nature where renewed political resolve might be found. Its persistence casts a shadow across the future of a multitude of wild plant and animal species, although protecting their populations from plunder is often far from easy. Demand for wildlife is often driven by complex socio-economic and cultural factors and in recent years these have combined with another global phenomenon – the internet – to create a challenging new frontier in the fight against wildlife crime.

As e-commerce revolutionises traditional business models, it also provides opportunities to traders in illegal wildlife. These include greater access to potential customers and, to date, few potential penalties, creating a high profit–low risk arena for criminal activity. To keep pace, new enforcement tools are required to maximise policing efficiency.

In recent years the threat posed by the illegal online trade in endangered animals has received increasing attention but the illegal trade in endangered plants remains under-investigated. Yet a growing body of research indicates that the rise of the internet has also greatly expanded the possibilities for plant trafficking. Rare and unusual plants can be ordered within a few clicks from a plethora of online outlets, with many buyers – and perhaps even some sellers – potentially unaware of the procedures required to ensure this trade remains compliant with national and international laws. In other cases, a minority of specialist collectors may specifically seek rare or newly described species. The internet enables connections to unscrupulous vendors to be made far more easily, and the demand for online sales from a global consumer base is likely to incentivise plant poachers. With overharvesting a proven threat to the wild populations of numerous plant species, there is an urgent need to understand the role that the internet plays in facilitating and driving this illegal practice, and to devise effective interventions to disrupt and prevent this overlooked threat to biodiversity.

There are significant hurdles to the monitoring of online trade in plants. The relative anonymity of the internet means that many illegal plant traffickers trade in 'plain sight' within easily accessible parts of the internet. Despite this, the enormity of the internet makes routine surveillance based on manual searches for evidence extremely costly in time and resources. Complex taxonomy and difficulties in distinguishing wild-sourced specimens from their cultivated counterparts create additional challenges for investigations.

It was with these considerations in mind that teams from the University of Southampton, the Royal Botanic Gardens, Kew and the UK's Border Force came together and initiated the FloraGuard project to apply an innovative, interdisciplinary approach to this conundrum. The project's specific objectives were to examine the internet-facilitated illegal trade in endangered plants and develop and test digital resources to assist researchers, law enforcement and other stakeholders striving to combat and curb these illegal online markets. The result is a proposal for a novel socio-technical approach to tackling internet-facilitated IWT, which combines adaptive artificial intelligence (AI) tools[1] with human judgement and expertise. While useful data relating to suspects and their online connections can be gathered by algorithms, keeping a human in the loop enables the context, behavioural patterns and sentiments surrounding this evidence to be explored.

This report provides an overview of the FloraGuard study, outlining the steps taken to refine and develop the proposed methodology. Other key findings are also presented, providing insights into the range of attitudes towards trade in CITES-listed species found within some online community forums. It is hoped these outcomes will aid the development of future enforcement practices to counter and disrupt IWT through the efficient gathering of online intelligence. Of equal value is the deeper understanding of these online spaces this interdisciplinary approach provides. This analysis may help generate ideas for alternative interventions, 'softer' than traditional enforcement, but potentially just as effective in deterring the use of cyberspace as a marketplace for some of the world's most threatened natural resources.

2. Background

2.1 The illegal wildlife trade – a persistent problem

Ariocarpus fissuratus

In 2020, environmental crime continues apace, consuming and unravelling the natural systems that underpin many aspects of human security and well-being. Growing at two to three times the rate of the global economy, it is now considered among the world's largest criminal sectors, after drugs, counterfeit crimes and human trafficking[2].

The combined market value of illegal logging, fishing and wildlife trade has been estimated at US$48–$216 billion[3]. However, when the loss of associated ecosystem services is factored in, the full economic damage of this illegal harvest has been estimated at $1–2 trillion per year[3].

Illegal wildlife trade is a persistent strand of this environmental harm. Driven by complex socio-economic and cultural factors, demand for wildlife products, with their high economic value and occurrence in remote, unguarded locations, can make wildlife susceptible to illegal exploitation. This applies to not only the world's iconic megafauna but to thousands of other animal and plant species, resulting in many being threatened with potential extinction. The loss of individuals from the wild also damages ecosystems. For range-restricted species, bouts of poaching could see entire genetic lines wiped out[4].

The impacts on human societies can also be catastrophic. With an estimated value of $7–23 billion a year, IWT denies emerging economies potential revenue while damaging sustainable livelihoods and opportunities for tourism[2]. IWT also extends criminality across borders, exploiting and criminalising vulnerable members of society, with serious societal consequences[5]. It also has serious ramifications for global health and security through the potential transmission of diseases to human hosts[6], a threat exacerbated by habitat degradation[7].

Combating this threat to biodiversity is complicated by the need to preserve the legal trade in wild-sourced products. Many resources are still harvested directly from nature, serving as important sources of food, medicines, construction materials and textiles. For trade into the European Union (EU) alone, the value of wild-sourced goods is close to €100 billion a year[8]. To ensure its sustainability, this legal trade, which supports millions of livelihoods around the world, must be carefully monitored and protected. That illegal timber harvests and related trade are thought to supply 10–15% of the global timber trade illustrates the challenges involved in achieving this[9].

With demand for wild products often arising in countries far from the species natural range, IWT frequently sees wildlife trafficked across international borders throughout the world. For decades it has persisted, changed and evolved, in contravention of one of the oldest conservation agreements in the world.

Encephalartos ferox

Rosewood being removed illegally from Marojejy National Park, Madagascar

TOPIC BOX 1: WHAT IS WILDLIFE TRAFFICKING?

Wildlife trafficking may be defined as the illegal trade of any wild plant or animal (including live specimens, dead parts, and derivative products) from the moment of initial capture, breeding or harvesting, to purchase by the final buyer[10].

For species listed in CITES Appendix I and II (see section 2.2), trade becomes illegal when it meets any of the following criteria[11]:

- International trade, where the specimen was not obtained in compliance with national legislation.
- International trade in wild-sourced CITES Appendix I species, for commercial purposes.
- International trade in wild-sourced CITES Appendix II species, without an approved CITES permit in place.
- International trade in artificially propagated or captive-bred Appendix I or II species, without an approved CITES permit in place.
- International trade in any non-exempt products containing parts and derivatives of CITES-listed species, without a CITES permit in place.

Several fires burning in the states of Rondônia, Amazonas, Pará, and Mato Grosso in Brazil

TOPIC BOX 2: WHAT IS A THREATENED SPECIES?

The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species, established in 1964, is the world's most comprehensive and authoritative source for the global conservation status of animal, fungus and plant species. Based on criteria relating to the status of wild populations, the threats they face and their projected decline, more than 112,000 species of plants and animals have been categorised, according to the following scale:

EX – Extinct	**VU** – Vulnerable
EW – Extinct in the Wild	**NT** – Near Threatened
CR – Critically Endangered	**LC** – Least Concern
EN – Endangered	**DD** – Data Deficient

A species is threatened if it is categorised as Vulnerable, Endangered, Critically Endangered or Extinct in the Wild.

While species threatened by international trade are frequently Endangered, or Critically Endangered, this is not a prerequisite for their listing within the CITES appendices, whose criteria instead relate to the impact that international trade is likely to have on a species, or upon species that it closely resembles. This means that upholding CITES regulations does not always directly involve species indicated by Red List categories to be threatened, although more often than not this proves to be the case[12].

2.2 The CITES regulatory framework

The Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) came into force in 1975. This agreement between 183 governments (Parties to the Convention) regulates the international trade in species of plants and animals that without these controls may be threatened by extinction through overharvesting. Its formation was, in part, a response to a recognition of the toll that increasing global trade would likely take upon species harvested from the wild. Its controls do not apply to domestic trade that occurs within countries, but imports, exports and re-exports of species included in the CITES appendices and traded internationally must comply with its regulations.

Since its inception, the number of CITES-listed species has steadily increased. Today, 37,000 species are listed within the CITES appendices, of which more than 30,000 are plants and around 5,800 are animals. While many of these are highly threatened, others are listed not because of their own wild population status but because they closely resemble a more threatened CITES-listed species. This prevents CITES-listed species being passed off as a less threatened lookalike, making CITES enforcement far more practical overall. Examples include the CITES listing of virtually all cacti and the entire orchid family (currently thought to number around 28,000 species[13]), which can be hard to distinguish when not in flower.

CITES protections may apply to all parts and derivatives, or just some of the various forms in which a species is traded. These may range from live specimens and seeds through to parts, derivatives and extracts.

To implement its controls, CITES issues permits for international trade. These must be supported by scientific evidence that the harvesting of the species in question is legal and sustainable. This assessment is known as a non-detriment finding and involves detailed research into the status of the species in the wild and sustainability of harvesting practices. This research is conducted by the management and scientific authorities of the country of export and, in some cases, also the country of import. While the cost of permits can be significant (e.g. in May 2020 the cost of a UK CITES export permit was £74), the permitting system and charges are complex and vary widely between countries. In some cases, charges may depend on the type of shipment and volume of goods involved, with charges lowered by some authorities for bulk items[14]. If the harvest is confirmed to have been conducted legally and sustainably, a CITES permit is issued. A CITES permit therefore acts as a

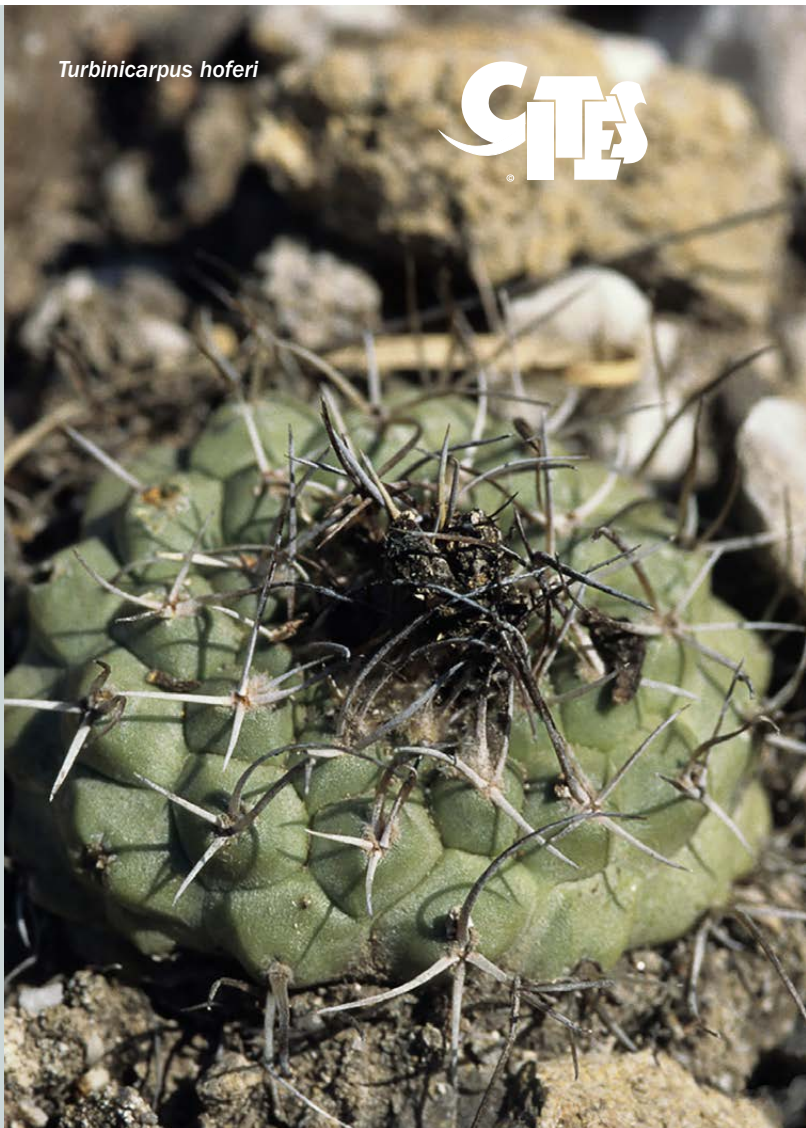
WHAT IS A CITES-LISTED SPECIES?

Species protected by CITES may be added to three lists, known as appendices, depending on the level of threat that international trade may pose for their survival.

CITES Appendix	Level of risk and protection
I	Species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances.
II	Species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilisation incompatible with their survival. Trade for commercial purposes is permitted, provided it can be demonstrated that this trade is not detrimental to the survival of the species.
III	Species that are protected in at least one country which has asked other CITES Parties for assistance in controlling trade. Unlike Appendices I and II, Parties that hold Appendix III listings are entitled to make unilateral amendments to them.

Source: www.cites.org

Decisions regarding additions to (or less frequently, removals from) the appendices, and changes to the annotations, take place every three years at a Conference of the Parties, after detailed consideration of the likely impacts of international trade upon the species' conservation status.



form of certification, to verify the responsible sourcing of the product[15]. The use of CITES permits is recorded in the CITES trade database, with this publicly available data enabling the volumes and trends in CITES trade to be monitored over time.

While CITES aims to protect wild populations, some specimens are produced in controlled conditions. Plants may be artificially propagated and animals captive bred, but this does not mean that they are irrelevant to CITES. On the contrary, the ways in which these specimens are produced is of central importance to the well-being of their wild counterparts.

2.3 The role of artificial propagation in plant conservation

The trade in artificially propagated specimens of CITES-listed species (the plant equivalent of captive-bred animals) is potentially of great benefit to conservation. Plant nurseries use various artificial propagation techniques, such as growing from seed or cuttings, to provide specimens of CITES-listed species to the horticulture trade. CITES-listed tree species grown for timber in plantations are also regarded as assisted production, and plants may also be cultivated in different settings for other purposes, such as the supply of medicinal products. Meeting market demand in this way ensures a supply of affordable, high-quality, disease-free plants, which takes the pressure off wild populations[16]. It also creates a sustainable and economically important industry in many countries around the world.

Even so, artificially propagated specimens are still subject to the provisions of CITES. This includes regulations to ensure the operation of plant nurseries is not detrimental to wild plant populations. For instance, any plants sourced from the wild to augment the nursery must be harvested sustainably, and only propagated offspring two generations removed from this wild-sourced parental stock may be sold[17]. Established nurseries can provide CITES officials with documentation demonstrating their adherence to these regulations. This process can be aided by registering the nursery with CITES[18], although relatively few businesses have taken advantage of this provision.

When preparing non-detriment findings for artificially propagated plants, it is important to verify that illegal, wild-sourced specimens are not being passed off as nursery-grown. Herein lies a significant challenge, as differentiating between artificially propagated and wild-sourced plants can be extremely difficult. In some cases, practical measures can be introduced to simplify the process for enforcement agencies. Examples include maximum size restrictions to

Of the more than 37,000 species that are currently protected by CITES, more than 30,000 are plants.

restrict the trade in mature plants, or a requirement to ship non-flowering orchids in uniform batches of 20 plants. While the plants themselves can hold many clues (see Topic Box 9), physical inspections may be inconclusive or impossible to perform.

Confirming the origins of artificially propagated plants therefore remains central to the CITES permitting system. This is not intended to deter trade and is only due to the ways in which illegal trade can masquerade as sustainable plant production. Due to the valuable role that artificial propagation plays in promoting the sustainable use of plants, artificially propagated specimens of Appendix I species, which are often highly threatened in the wild, may be traded under the more relaxed provisions of Appendix II.

2.4 CITES strengths and weaknesses

Forty-five years after coming into force, CITES remains a powerful tool in the fight against IWT. The stringent permitting system deters trade in illegally sourced specimens, while specimens of CITES-listed species shipped without permits can be seized by customs authorities, with offenders potentially facing prosecution. Serious or persistent infringements can be referred to the CITES Secretariat, who may issue sanctions against countries in the form of trade bans, frequently accompanied by an offer of help to resolve the underlying issues. CITES was conceived in the spirit of cooperation, but this mechanism of last resort remains a powerful way to protect CITES-listed species. Such cooperation has seen some likely extinctions averted[16], and CITES remains central to international efforts to alter the trajectory of many species facing over-exploitation due to their actual or perceived usefulness to humans. Listing species within CITES does not, however, guarantee salvation, due to the considerable implementation challenges that exist.

While the principles of CITES are robust, there are certain vulnerabilities that can be exploited or that create unintended criminal opportunities. Firstly, as CITES acts as a framework that is open to interpretation, the ways in which it is enforced vary between countries[14]. This is further complicated by a lack of capacity within some countries to conduct the scientific research that underpins the permitting process, or to adequately train and resource enforcement teams[19].

Technical difficulties include challenges in identifying species in trade (particularly once they have been processed into finished products) and confirming their provenance (as noted in the previous section on artificially propagated plants). Fraud, corruption, and non-compliance can also undermine the CITES permitting system[2]. Non-compliance is particularly

TOPIC BOX 3: CITES REGULATIONS WITHIN THE EUROPEAN UNION

CITES is a multilateral agreement, which leaves the implementation of its regulatory framework open to interpretation by individual Parties. The approach taken by the EU is particularly distinctive. Here, CITES is implemented through the European Commission Wildlife Trade Regulations. These translate the CITES appendices into a series of annexes – broadly similar in nature, although applying stricter controls to certain species.

EU Annex	Includes
A	• All CITES Appendix I species. • Some CITES Appendix II and III species, for which the EU has adopted stricter measures. • Some non-CITES species.
B	• All other CITES Appendix II species. • Some CITES Appendix III species. • Some non-CITES species.
C	• All other CITES Appendix III species.
D	• Some CITES Appendix III species for which the EU holds a reservation and does not apply CITES regulations. • Some non-CITES species. • There is no Annex D equivalence within CITES itself.

Source: ec.europa.eu

The EU approach to permits also varies from that of most other Parties. For Appendix II (Annex B) specimens, CITES only stipulates that a CITES export permit from the country of origin is required. The EU, however, requires that an import permit is also issued by the country receiving the goods. This double permit approach provides the EU with a detailed oversight of CITES species in trade and enables it to impose its own trade advice and/or sanctions, creating a useful additional safeguard against irresponsible and illegal trading.

Once a specimen has been accepted into the EU, it may be freely moved between EU member states without the need for additional CITES permits. Following the end of the Transition Period, this free movement may be replaced by a CITES permit system for trade between the UK and EU member states. This means e-commerce between the UK and EU countries may become another potential source of CITES non-compliance, with consumers unused to the permitting procedures potentially at risk of unintended breaches.

Orchids growing in
industrial nurseries

relevant to internet trading, which may result in numerous small (and therefore difficult to monitor and intercept) postal shipments. A delay of 18 to 24 months before CITES trade records are submitted and uploaded to the trade database also makes it harder for CITES authorities to assess and respond to emerging trends. Originally developed for physical borders and reliant on paperwork, the CITES system faces a host of issues that complicate its enforcement in the digital world.

2.5 Internet-facilitated IWT

The internet has become the largest global marketplace[20] thanks to a multitude of advantages that it offers to both traders and consumers. No matter how highly specialised a market may be, it is far easier to find potential customers online than in the physical world[10]. With the projected growth of the global digital population this business opportunity is only set to increase.

These advantages have not been lost on criminals. As the internet has evolved, so too has cybercrime, from low-volume activities performed by specialists into more mainstream, high-volume forms of crime. Yet precisely how the internet is exploited by criminals remains under-investigated. This is particularly true of wildlife crime. While the significance of the internet as a means to traffic wildlife is widely acknowledged, the full scale and scope of this illicit activity remains undetermined[20–22].

Various terms are used to describe the illegal trading of wildlife through online sales or arrangements. These include wildlife cybercrime, the illegal online trade in wildlife, wildlife trafficking online and wildlife trafficking linked to the internet. In criminology, the term internet-facilitated wildlife crime has also been introduced, to reflect that internet-mediated wildlife trafficking is a hybrid market that merges the traditional, social and economic opportunities of these crimes with opportunities provided by the internet[10]. This serves as a reminder that wildlife crime does not exist because of the internet but may be aided by its use.

For illegal wildlife traders, one major attraction of the internet is the ready connection it enables with specialist buyers interested in species-specific products[23]. Other advantages include convenience, low operating costs, the lack of physical inspection of goods prior to purchase, and the rapid and secure communications and financial transactions that can be achieved[8, 20]. Above all, the internet offers illegal traders anonymity and distance from scrutiny, which may encourage participation and ease barriers into certain forms of wildlife trafficking[24].

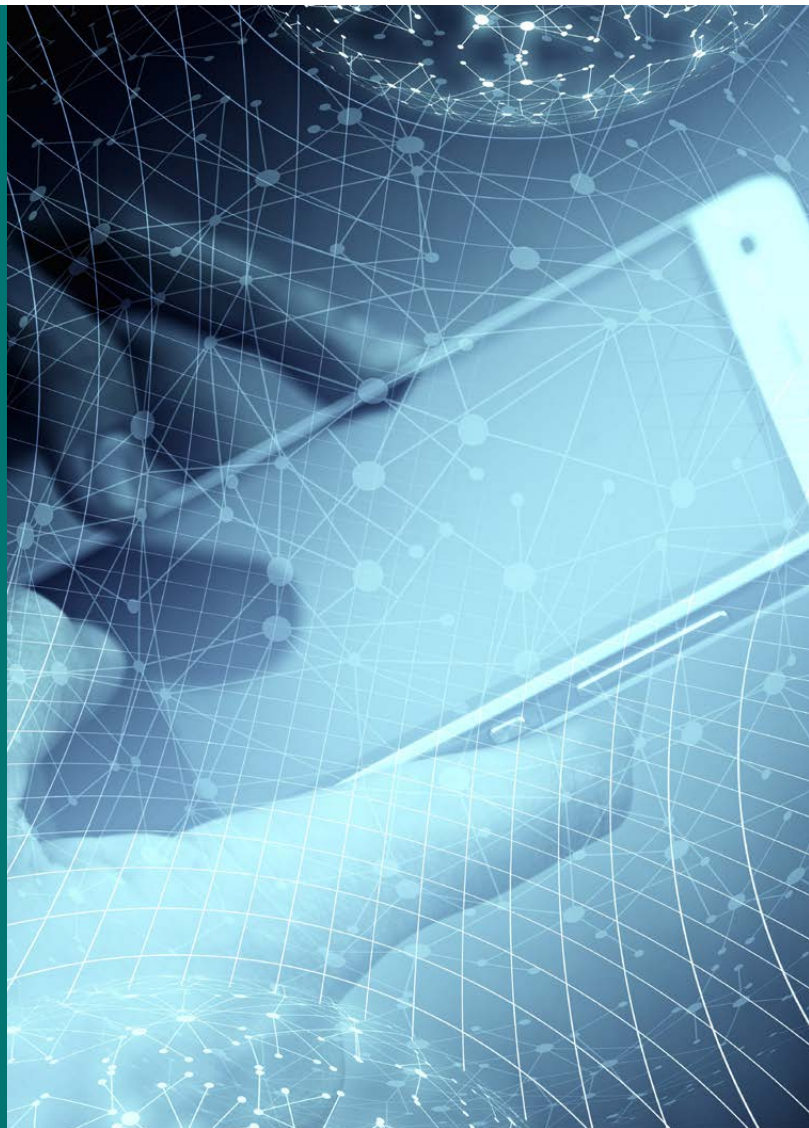
TOPIC BOX 4: GROWTH OF THE GLOBAL DIGITAL POPULATION

The World Wide Web fully justifies its name. As of January 2020, there were more than 4.5 billion active internet users, representing 59% of the global population. This includes more than 2 billion users in Asia, and over 700 million within Europe[27].

Yet the global reach of the internet shows no sign of slowing down. It is predicted that global internet traffic will increase three-fold between 2017 and 2022. The highest growth (+41%) is forecast to occur in the Middle East and Africa, followed by Asia Pacific (+32%). Over this five-year period, the number of networked devices is also expected to increase from 18 billion to 28 billion – more than three devices for every person on the planet[28].

These projections suggest that in the coming years unprecedented numbers of people will be online, with the demographic of users also set to widen as use of this technology becomes increasingly routine.

This rapid surge in online use will dramatically increase the number of marketplaces and potential consumers available to traders in illegal wildlife. Unless highly effective interventions are developed and implemented, these projections suggest an even more daunting challenge lies ahead for enforcement agencies.



To date, the majority of research into internet-facilitated IWT has focused on fauna. The online trade in ivory, in particular, has received much attention[6, 25], although investigations regularly observe thousands of specimens representing all of the major animal groups – from invertebrates to primates[20] – being traded. By contrast, the internet's role in the trade in endangered plants remains relatively unexplored. However, in recent years a growing number of studies have begun to illuminate the role online markets play in the illegal trade of many species of threatened flora[26]. They also highlight the significant knowledge gaps that need to be filled if this problem is to be successfully alleviated and controlled.

The internet offers illegal traders anonymity and distance from scrutiny, which may encourage participation and ease barriers into certain forms of wildlife trafficking.

TOPIC BOX 5: A WEB OF MANY LAYERS: WHERE DOES INTERNET-FACILITATED IWT TAKE PLACE?

In terms of content accessibility, the internet can be divided into three layers. The term 'surface web' refers to classic web pages that are static and relatively searchable, as their URI (uniform resource identifier) provides same page every time. By contrast, 'deep web' refers to those parts of the internet less readily accessible to search engines. These may be pages behind logins or paywalls, or that are dynamically computed from a database. They cannot be readily indexed as they are either inaccessible to crawlers or provide different content each time. The third layer is the 'dark web', accessible through the Tor network which uses protocols to provide anonymity.

To what extent wildlife traders use the dark web is unclear. Research published by INTERPOL in 2017 suggests that IWT may be conducted on the dark web, although evidence from a number of studies suggests this remains rare for both animal and plant products[29]. These findings are supported by the widespread use of the surface web to advertise and sell illegal wildlife products. The lack of effort to conceal this activity suggests that for illegal traders the benefits of using the surface web still far outweigh the perceived risks[10, 30]. With greater attention focused on policing the surface web, it is conceivable that deep and dark web-facilitated IWT may require more attention and specific measures in future.

3. The threat to plants

3.1 Internet-facilitated trade in threatened flora

CITES-listed plants are traded for a multitude of reasons, reflecting their intrinsic role in human lives. This includes their use as construction materials, tools, medicines, foods, ornaments and cosmetic products, and may see them traded as live plants, timber or derivatives such as oils, extracts and powders. Such trading ranges from large-scale commercial operations through to subsistence users[11].

Cultural factors and the increase in global population add to the pressure on wild plant populations. Horticulture has undergone something of a boom during the past 60 years, aided in part by the increased affordability of greenhouses, and is now a major contributor to this demand[16]. Other species are traded for timber, or as derivatives including powers, oils and extracts. Globally, more than 60,000 plant species are used for their medicinal properties; around 3,000 of these are thought to be traded internationally. Traditional Chinese Medicine (TCM) is 80% plant-based and nearly three quarters of the species used are harvested from the wild, amounting to almost one third of overall production. Assessing the impact of this trade can be difficult, as only 7% of medicinal and aromatic plants have had the threats to their survival assessed. Of these, 20% are threatened with extinction in the wild, based on the IUCN Red List criteria[15, 31].

Compared with research into the trade in fauna, relatively few studies have examined the role that the internet plays in facilitating global trade in flora. Those researchers who have examined this trade in detail often uncover alarming evidence to suggest that the use of online platforms by illegal plant traders is of growing concern.

The online cacti trade has been the focus of some research. Cacti are an economically and culturally important plant group, prized as house and landscape plants. While most cacti trade is sustained by artificial propagation, demand for wild specimens continues to pose a threat, particularly to newly discovered populations or species, or as a result of new horticultural trends [32]. Since 1976, when CITES trade database records began, around three quarters of the world's 2,000 cacti species have been documented in trade, including more than 300 considered threatened by the IUCN[33]. Trade in cacti has spiked, particularly within the last decade. This includes a 64% increase in domestic US trade between 2012 and 2017, creating a multi-million dollar market[4]. While the majority of this trade involves nursery-grown plants, over-collection of wild plants and seeds is considered a principle threat to almost a third of IUCN Red List cacti species, making transparency within the industry of paramount importance[34].

Several studies have raised concerns over the degree of potential CITES non-compliance connected to the sale of cacti online. A 2013 study compared online sales of cacti with the official records of the CITES trade database and concluded that nearly 90% of this trade was likely taking place without CITES permits[35]. In 2016, species of *Strombocactus*, a genus native to Mexico, were found for sale on 32 European online marketplaces. The percentage of these outlets that appeared to provide CITES documentation for international trade ranged from 17% in Germany to 25% in the Czech Republic, 33% in France and 50% in Italy. Of those that did, five stated that CITES papers were necessary for export but that this was the buyer's responsibility to organise. Overall, only 38% referenced the use of artificial propagation techniques, although further evidence to support these claims was not necessarily displayed. Based on these results, the authors described the internet as an open door for illegal trade[26].

In 2017, 109 threatened cacti species were recorded for sale on 11 internet auction sites. While the majority of sales corresponded with legal CITES records, adverts' use of generic or common names, or non-existent scientific names made it impossible to verify which species were being traded in more than a third of cases[33].

Orchids are another highly traded plant family, consistently rated among the most popular potted plants worldwide. Between 1996 and 2015, around one million wild-sourced orchids were recorded in the CITES trade database, along with more than one billion artificially propagated specimens. In recent years, the role of online marketplaces in orchid trade is thought to have grown substantially, with the potential for illegal trade considered a significant threat to some species[11].

It is no surprise then, that vast amounts of orchid-related online traffic are generated. A 2016 study of around 55,000 social media posts over a 12-week period found that 9% involved the sale of plants. Of these, 22–46% of plants were considered potentially wild sourced and of dubious legality[30]. The sale of wild orchids within e-commerce websites and hobbyist forums illustrates the scale of monitoring required to comprehensively track and understand this market[23].

A smaller number of studies have assessed the online trade in plants common to particular geographical regions. A 2013 study of trade in species endemic to Greece discovered that 117 species, representing around 10% of the country's

endemic flora, could be purchased from nurseries in Europe, North America and Australia. A lack of transparent information online made it impossible to determine the extent to which this trade may have been legal[36]. In 2017, a similar study revealed species representing 34% of Cypriot endemic flora, including endangered and critically endangered species, were being offered for sale online by nurseries in Europe and North America, although how they may have originally entered these markets was unclear[36].

The responsibility for ensuring that trade is being conducted sustainably lies with both buyers and sellers. Given the complexities of CITES, it is conceivable that for some, ignorance of the rules may lead to inadvertent breaches. In other cases, non-compliance appears to be associated with more calculated risk taking, along with negative perceptions of the CITES regulations. A 2016 survey of 800 orchid collectors found that around 10% admitted to some form of smuggling, nearly 5% admitted to laundering plants, and more than 10% had received orchids from online purchases without the correct paperwork in place. Those with a greater knowledge of the rules tended to engage in more active forms of non-compliance, suggesting they may hold negative opinions of CITES regulations, and presumably perceive the risks of being caught as very low[30]. These results are concerning, as while the vast majority of orchid collectors are engaged in responsible forms of trade, for threatened species considerable damage may be done by a small number who choose to circumvent the rules.

The risk is particularly acute for newly described species, for which novelty and rarity can be dangerous attributes. Due to the preference of some collectors for the rarest plants[37], these species can attract high prices, incentivising their rapid collection and entry into trade. The slipper orchid *Paphiopedilum canhii* offers a dramatic example. Discovered in Vietnam in 2010, within 6 months 99% of known plants had been collected from the wild, placing the species at the brink of extinction. This type of gold rush is not restricted to orchids. Newly described species of Mexican cacti have also been found online within months of their discovery[38].

As well as directly facilitating illegal transactions, the internet can threaten the security of wild plant populations in other ways. The sharing of images online can fuel demand from specialist collectors[23, 39], while social media may exacerbate the problem of tourists stealing souvenirs[4]. The GPS coordinates of wild populations may also be circulated online, enabling poachers to target specific locations with ruthless efficiency[4]. Examples include 11 people investigated for poaching and online sale of rare cacti from Chile, Argentina and Peru, whose wild locations had been geo-referenced using information from the internet[10].

Plant poaching shows no sign of abating. In January 2019, specimens of *Sclerocactus havasupaiensis*, a cactus only found within a specific section of the Grand Canyon, appeared in an online auction in Ukraine[4]. In January 2020, poachers were apprehended in South Africa in possession of more than 60,000 succulents including many *Conophytum* species[40]. Some of these plants are thought to be more than 200 years old, and while intercepted before the point of sale, it is conceivable that the internet could have been used to facilitate their trafficking.

While poachers often target live plants for horticulture, online sales of medicinal and aromatic plants are also relevant when considering the impacts of internet-facilitated IWT. This includes more than 365 CITES-listed species traded for their medicinal properties in the form of live specimens or as products and derivatives. In 2017, a survey of Amazon and eBay adverts relating to these species found that of 660,000 posts across the two sites, only 58 referenced CITES within their product descriptions, making it hard to judge whether CITES documentation was being used for transactions. The same study recommended that 26 species needed further research, due to high demand[41]. This includes *Saussurea costus*, a species which regularly ranks highly among the number of illegal plant seizures made by border agencies around the world[42].

This growing body of research strongly suggests that the internet provides a wide range of opportunities for illegal plant traders to exploit. This presents considerable challenges to the enforcement agencies charged with combating the illegal global trade in wildlife.

A 2016 survey of 800 orchid collectors found that around 10% admitted to some form of smuggling, nearly 5% admitted to laundering plants, and more than 10% had received orchids from online purchases without the correct paperwork in place.

Hoodia gordonii

TOPIC BOX 6: MOTIVATIONS BEHIND THE DEMAND FOR ILLEGAL WILD-SOURCED PLANTS

The demand for species targeted by IWT is driven by a complex array of socio-economic and cultural factors. Where species possess properties that are considered unique, it can be difficult for substitutes to be deemed acceptable[43]. These factors are evident in the sometimes-high demand that exists for many species of rare and threatened plants.

The appeal of novelty to humans is well-understood. For some horticultural collectors, a preference for rare, wild-sourced plants may be accompanied by a desire to be the 'first' to own new or unusual varieties[37, 44]. As specialist collectors have the expertise to grow and sustain collections of rare plants[11], the possibility of producing new hybrids for interest and/or financial gain may provide added incentive[39].

A preference for wild-sourced plants as ingredients for derivative-based products may also arise due to real or perceived differences in the quality or concentration of their active ingredients[15]. Premium prices for such 'authenticity' may encourage illegal collection from populations where unregulated harvest would not be sanctioned by CITES management authorities. In other cases, artificially propagated varieties of some species may simply not exist, with trade from wild populations requiring careful oversight to prevent unscrupulous traders from harvesting incorrectly or beyond quota limits. It should also be recognised that the cost and timeframe of obtaining CITES permits may be off-putting for some vendors, particularly those trading in small quantities.

Where these factors make responsible business models economically unfeasible, it might be reasonable to assume that the temptation for non-compliance grows stronger.

Not all illegal trading is deliberately conceived. In some cases, non-compliance with environmental regulations such as CITES may stem from ignorance or naivety, enacted by consumers who are confused or have a poor understanding the rules[45]. Plant adverts on well-known online platforms may also help to legitimise illegal trade, lowering the guard of consumers who may assume that the necessary checks and balances are in place[26].

Identifying the behavioural drivers behind the illegal trade in threatened plants is central to the development of strategies designed to curb this demand. Understanding how those involved in illegal trade make sense of their lifestyle, gain satisfaction from their acts and organise themselves socially is likely to be particularly important for tackling internet-facilitated IWT[24]. While traditional law enforcement can be challenging to apply in online settings, offenders may be more easily reached by other forms of intervention and persuasion, tailored to their particular sensitivities and delivered via the internet itself.

TOPIC BOX 7: CYBER-HOTSPOTS

Research indicates that internet-facilitated IWT often revolves around cyber-hotspots of activity. These include specialist commercial websites, forums, blogs and other forms of social media, which create virtual spaces where people with particular interests can meet. These may extend across international boundaries, placing them beyond the reach of any single law enforcement jurisdiction, although they are not necessarily closed environments and, in some cases, their users may also meet in the physical world[10].

Cyber-hotspots are a recognised feature of many forms of cybercrime, and evidence suggests that they also play a significant role within IWT. For instance, a 2016 Wildlife Justice Commission investigation identified an online criminal network setting up hotspots based around the Facebook and WeChat platforms to help sell wildlife products valued at $50 million[20].

Identifying cyber-hotspots of relevance to internet-facilitated IWT presents a considerable challenge, given the sheer number of online hotspots. A 2016 study of orchids traded via social media identified 150 separate interest groups, whose combined membership exceeded 43,000. Of these, 28% of the groups permitted trade or allowed it to occur, with trade conducted in a number of languages across highly connected networks[30].

Connections and relationships that may exist between the users of a cyber-hotspot may also be very different to connections formed in the real world, with the online environment altering an individual's level of influence and the mechanisms by which trust between users is earned[24]. One study noted that understanding the relationships that exist between potential online criminal actors, including their stability or duration and the occurrence of subgroups and bottlenecks of activity, is of direct relevance to enforcement operations[46]. For instance, the removal of key people may have a secondary, wider effect within the cyber-hotspot in which they exerted influence. A deeper understanding of cyber-hotspots is therefore crucial to the development of strategies designed to counter and disrupt internet-facilitated IWT.

3.2 Enforcement challenges

The challenges of maintaining law enforcement online are manifold. The fast-evolving nature of cybercrime pits enforcement agencies against technologies and concepts that may not have existed even a decade ago[47]. When coupled with the often relatively low priority of wildlife crimes, it is little surprise that the resources and specialist expertise required to counter internet-facilitated IWT are frequently lacking in many police forces internationally[6]. The sheer scale of the internet, and the speed at which online marketplaces proliferate, makes the monitoring of online criminal activity extremely costly in time and resources. Even with specialist knowledge and training, readily distinguishing legal from illegal trade can be difficult.

This enables offenders to enter illegal markets with relatively little risk of being caught and, while the penalties for high profile wildlife crimes are beginning to stiffen, illegal traders may be further emboldened by the often-inadequate level of prosecutions and punishment that culprits receive. For instance, a 2015 survey of international orchid hobbyists found that punishments for breaches of CITES regulations were of low concern among respondents, even though some had admitted to certain transgressions[51].

As evidence of adherence to CITES regulations is rarely a legal requirement at the point of sale, the omission of these details from online adverts does not necessarily provide proof of illegal intent. Furthermore, as the final transaction may be conducted via private or offline modes of communication[8, 48] and domestic in-country sales do not require CITES permits, identifying illegal activity is a complex process[20]. The long lag time before legal CITES shipments are available for public analysis also makes it more difficult to compare online trade with documented sales activities.

The anonymity of the internet also enables suspects to conceal their identities. Efforts to combat IWT often involve targeting specific links within chains of criminal actors, extending from front line poachers, through middlemen facilitating transit, and traders who pass the products on to the consumer[10]. Online, key communications can be sent via closed networks or through private online services such as direct messaging apps, social media, encrypted channels and hidden parts of the internet such as the dark web, making their activities harder to track[20]. While e-commerce platforms may provide some information relating to the vendor and their products, similar details for buyers are usually unavailable[11]. Use of covert surveillance to infiltrate these barriers is intrusive and greatly complicates investigations, and suspects' rights to privacy must be carefully considered before taking such extreme action.

The trade in plants also poses unique technical challenges. Identifying species can be complicated by vendors placing adverts using incorrect plant names, only naming species to genus level, or using slang or abbreviations to indicate species or growing conditions (such as 'Paphs' for Paphiopedilum)[33, 49]. The use of incorrect names may be intentional, as 'tagging' a plant with a more popular species name may help draw attention to the post. Illegal wildlife traders may also use code words to advertise sensitive products while remaining under the radar of trading regulations. This has been observed in the online sale of banned ivory items[50], although does not appear to have yet been employed to facilitate the illegal sale of plants[49].

Differentiating wild-sourced from artificially propagated specimens using information available online can also be difficult, even for horticultural experts. The use of online images may provide useful clues, although a number of caveats may mean these are unable to offer definitive proof of wild sourcing (see Topic Box 9). For newly described species, the timeframe required to produce legal specimens through artificial propagation (i.e. two generations removed from the parental stock) can be calculated to monitor their entry into trade. For example, it takes 22 to 66 months to produce artificially propagated specimens of *Paphiopedilum* orchids in accordance with CITES regulations, so specimens traded online before or within this timeframe are more likely to have been illegally produced. This approach could be applied to a wide range of plant and animal species, although it would require adequate monitoring of the internet during the critical time periods that follow the discovery of a new species of interest to illegal traders[51].

Pursuing evidence may be further complicated by the fact that traditional law enforcement does not translate well into cyberspace. The jurisdiction of enforcement agencies may not extend to the source of the crime[21], while geographic legislation variations, harvesting restrictions, legal ambiguities and the differences in cross-national agencies' ability to investigate and prosecute these crimes gives criminals ample opportunity to evade detection. As plant products traded online are frequently shipped via postal or courier services, there is also less opportunity for specimens without customs declarations to be intercepted and physically inspected by customs officials. This is not to say that inspections of the post are not made, with illegally trafficked wildlife detected through the use of scanners and routine inspections [52]. Operations specifically targeting the postal service have also been undertaken, such as Operation Quiver, a collaboration between the UK Border Force, National Wildlife Crime Unit and Royal Mail which targeted ivory products leaving the UK by post[53]. However, arguably it is easier to detect illegally trafficked animals (particularly live specimens). Plants do not leave a heat signature and may show up less clearly on security scanners.

Despite these challenges, opportunities to use the internet to counter IWT exist, and the important role of online intelligence in real-world interventions has been demonstrated. This includes its use within the Thunder series of international enforcement operations. In 2017 Operation Thunderbird examined websites and social media posts offering wildlife products for sale. This contributed to the success of 49 countries in identifying 900 suspects and making 1,300 seizures of illicit products worth more than $5 million, including 300 tonnes of wood and timber [54]. In 2019, Operation Thunderball saw 109 countries coordinate

to identify 600 suspects, with seizures including 2,600 plants, and 2,500 m^3 of timber. In reporting the operation, INTERPOL highlighted the role that online investigations played in making 21 arrests in Spain, and the seizure in Italy of 1,850 illegally trafficked birds[47].

In addition to these major international operations, the monitoring of online platforms can also lead to other successful convictions for wildlife crime. In 2017–2018, attempts to sell rhino horn and ivory online resulted in jail sentences and fines for the perpetrators involved[20]. In the UK in 2016, a person from Cumbria was convicted of poaching 5,000 bulbs of protected plant species, including CITES-listed snowdrops (*Galanthus nivalis*). While online intelligence did not lead to their capture, the investigation revealed that the bulbs had been offered for sale on eBay and Amazon, with adverts falsely declaring that they had been artificially propagated. In addition to breaching the UK's Wildlife and Countryside Act (1981) and the Control of Trade in Endangered Species laws which regulate the trade in CITES-listed species, this detail also incurred the charge of 'fraud by misrepresentation', contrary to the Fraud Act (2006). The conviction resulted in a fine for the perpetrator, and the uprooted bulbs were replanted in the wild by volunteers.

As these examples demonstrate, focusing time and resources on gathering online intelligence can help detect and prosecute wildlife trade offenders. Tools, resources and policies to make the online trade in plants less opaque would help build on these successes and tip the odds more in favour of law enforcement.

3.3 Recognition by the international community

In recent years, the use of the internet to facilitate IWT has gained increasing attention from a number of global authorities. As the scale of the threat is recognised, efforts to coordinate responses continue to grow. The following offers a brief summary of some of the key pillars supporting the global struggle against this pervasive form of IWT.

International conventions and agreements

Efforts to combat the illegal wildlife trade are led by governments' commitments to provide the resources and cooperation required to address wildlife trafficking in all its forms. In recent years, internet-facilitated IWT has been increasingly acknowledged within global conversations and agreements.

U.N. Secretary-General Ban Ki-moon opens World Wildlife Day Exhibition, 2014

For more than a decade, CITES has raised awareness and coordinated national responses to the threat posed by online trade. Since 2017, it has facilitated the Wildlife Cybercrime Working Group, with representation from 25 countries across four continents[20]. The CITES Secretariat also encourages Parties to establish national-level units dedicated to investigating wildlife crime linked to the internet[17], and encourages sharing of information to help develop best practice models[18].

Similar intentions for coordinated action have also started to emerge within the commitments and legislation of other global authorities. The priorities of the 2016 EU Action Plan Against Wildlife Trafficking recognise the need to address the root causes of wildlife crime and the importance of strengthening partnerships between source, consumer and transit countries. The need to increase capacity for tackling the links between wildlife trafficking and organised crime, including cybercrime, is also recognised[55].

In 2017, a resolution on internet-facilitated IWT was adopted by the United Nations General Assembly, which acknowledged the need for cooperation between governments to tackle this issue. Internet-facilitated IWT has also been raised at the United Nations World Crime Congress and the G7, with commitments made by six governments to strengthen their legislation in this area[20].

Effective action against IWT also contributes to the 2015 Sustainable Development Goals, the UN's blueprint to achieve a better and more sustainable future for all. The urgent need to prevent poaching and trafficking of protected species, and reduce the demand for these products, currently falls under goal 15, Life on Land, which includes halting biodiversity loss within its aims[56]. It also aligns with target 4 of the Convention on Biological Diversity's Aichi Biodiversity Targets, which covers the sustainable use and consumption of natural resources[57], and with target 11 of the Global Strategy for Plant Conservation, which states that no species of wild flora should be endangered by international trade[58]. The renewal of many global biodiversity targets is due to be agreed at the Convention on Biological Diversity's fifteenth Conference of the Parties. Commitments to ensure legal and sustainable harvesting and trade in wild species will form an important component of any new framework[59], although at the time of writing it is unclear to what extent internet-facilitated IWT may be specified within these objectives.

International enforcement authorities

Within the world's top enforcement bodies, cybercrime and wildlife crime have long been viewed as separate entities. Recently this has begun to change, with IWT now increasingly incorporated into the research and monitoring of cybercrime activities[8].

The International Criminal Police Organization (INTERPOL) has a long-standing role in combating transnational organised crime, and an increasingly important role in the countering of cybercrimes. In 2014, this renowned institution established the INTERPOL Global Complex for Innovation to facilitate cooperation between law enforcement and the private sector in detecting and preventing digital crime[8]. Their work has included an assessment of the dark web as a source of wildlife trafficking (see Topic Box 5). INTERPOL also has the capability to lead global and regional operations, and to provide the training that enforcement agencies require to tackle IWT. This includes practical guidelines only available to law enforcement practitioners on how to combat wildlife crime linked to the internet.

The United Nations Office on Drugs and Crime is another important source of international support, one with capacity for research and field-based projects and training[60]. Due to its transnational nature, wildlife crime is considered highly relevant to the office's work.

The European Union Agency for Law Enforcement Cooperation also plays an important role in combating wildlife trafficking and the implementation of CITES regulations within EU member states[61]. Since 2011, it has recognised the internet as a facilitator of organised crime, although wildlife crime has not received the same level of systematic analysis as other traditional market-based crimes such as drugs and human trafficking[10].

At the forefront of efforts to counter cross-border trafficking of all types is the World Customs Organization, an independent intergovernmental body representing 183 customs administrations who, together, process 98% of global trade. In its efforts to combat IWT, the World Customs Organization conducts research into the governance of wildlife trade, and regularly undertakes major global enforcement operations such as the 'Thunder' series, which is coordinated in partnership with INTERPOL. In recent years it has included internet-facilitated IWT within capacity building activities.

National-level action

In many countries, the global response to internet-facilitated wildlife trade needs to be translated to action at national level. While not an exhaustive list, Table 1 provides some illustrative examples of the legislation and other interventions that have so far been developed at national level.

These national and international actions are encouraging but future global action to combat internet-facilitated IWT will require even greater coordination. Many countries are yet to report specific actions to address online IWT[8], while measures designed to counter the illegal trade in plants appear to be lagging behind those specifically tailored towards fauna. For many countries, support from the global community will be vital to build the technology and expertise required to keep pace with the ongoing evolution of internet-facilitated IWT.

3.4 Online platform policies

Online technology companies have strong ethical and commercial reasons for wishing to prevent trade in illegal wildlife products occurring across their platforms. The difficulties in policing this trade via traditional means, also means they have a pivotal role to play in devising and implementing effective intervention strategies.

TABLE 1:

Examples of national-level actions taken to combat internet-facilitated IWT

Country	Organisations, actions and legislative measures
China	• In January 2017, the Wild Animal Protection Law came into force, forbidding online trading platforms to provide services for the illegal sale, purchase and use of wildlife products. This is the first time that Chinese legislation has specifically highlighted wildlife cybercrime[8].
Czech Republic	• The Nature Conservation Agency of the Czech Republic enforces Act No. 100/2004, Gazette on the protection of species of wild fauna and flora. Any sale offers, including internet adverts, are obliged to include details of supporting CITES paperwork and, on request of the Czech Environmental Inspectorate, traders must be able to prove a specimen's origin. However, this level of transparency only applies to specimens of certain species subject to registration and those listed in Appendix A of the EU's own CITES regulations. It does not apply to the more widespread trade of Appendix II specimens[62].
Germany	• The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety has formally recognised the importance of collaboration between policymakers, authorities and online marketplaces for tacking wildlife cybercrime[8].
Kenya	• In 2017, the Kenyan government launched the Computer and Cybercrime Bill. The government also called for greater investment in cyber security by the private sector, as the number of online devices (particularly smart phones) within the country was expected to increase by more than 40 million in the following year[63]. The new legislation does not list wildlife cybercrime as a specific offence[8].
Thailand	• In Thailand authorities have used social media to post information and advice about the trade in certain species of orchid. In 2018, a warning about the threat that sales of illegal plants posed to the country's orchid industry reportedly saw a number of online adverts for these species withdrawn by sellers[11].
United Kingdom	• In the UK, CITES legislation is implemented through the Control of Trade in Endangered Species (Enforcement) Regulations (1997). In October 2018, a requirement was added for adverts to display details of sales certificates issued under Article 10 of the EU Regulations[64]. As these certificates only apply to CITES Appendix I (EU Annex A) specimens, it does not regulate the majority of CITES-related trade that occurs online, which is of Appendix II species (or artificially propagated specimens of Appendix I/Annex A plants). An earlier 2015 legislative review recognised the increasing role of the internet in facilitating trade in CITES-listed species but concluded there was insufficient evidence of the threat it posed to listed species to warrant further measures, such as pop-up windows providing consumers with CITES information. The review was also concerned that heavy handed interventions might drive online trade underground, and that a carefully considered approach drawing on experiences from other areas of online policing would be required[65]. • UK enforcement is overseen by the National Wildlife Crime Unit. The actions of law enforcement, government, non-government and civil society organisations are coordinated through the Cyber Enabled Wildlife Crime Priority Delivery Group, which develops strategies to tackle internet-facilitated IWT within the UK, although where appropriate international assistance is provided[66].
United States	• The United States Fish and Wildlife Service has long recognised the need for a smart response strategy for tackling internet-facilitated IWT. Service investigators and intelligence analysts are trained in cybercrime techniques and collecting online evidence[67]. Specialist operations include Operation Cyberwild in 2011 and Operation Wild Web in 2012, although these appear to have been focused on trade in endangered animal species[68, 69]. Other strategies have included raising corporate awareness with online platform providers[67]. • In 2016, the US Agency for International Development funded a wildlife crime tech challenge. The challenge was won by a team from New York University, who developed the Enforcement Gaps Interface tool, which searches for hidden wildlife adverts using data mining and image recognition[70].

CITES offers specific advice to Parties to guide their approach in working with technology companies. This includes encouraging online platforms to introduce suitable terms of use, raising public awareness of wildlife crime linked to the internet and encouraging the cooperation of postal, transport and financial service providers[17].

Faced with evidence that their services are being abused by illegal wildlife traders, many online technology and e-commerce companies have taken commendable actions in stepping up to this challenge. The Coalition to End Wildlife Trafficking Online is among the most notable. Launched in 2018 by the World Wildlife Fund, the International Fund for Animal Welfare and TRAFFIC, this international initiative brings 34 global tech companies together to proactively tackle internet-facilitated IWT through the development of platform-specific action plans. This coordinated action has led to the development of standards and advertisement policies and the training of enforcement staff. Platform users have been taught to report suspicious items online and through stakeholder collaboration digital tools to monitor online wildlife trade have been enhanced.

By March 2020, companies in the coalition reported removing or blocking over three million endangered species listings from their platforms, and volunteers in its cyber spotter programme had flagged over 4,500 suspicious products. Other positive actions from these tech giants range from Facebook's banning of all CITES Appendix I products to an Instagram pop-up alert linked to relevant search terms, and China's Tencent uncovering criminal networks and conducting positive community outreach. These achievements emphasise the private sector's important role in combating IWT, a point highlighted at the 2018 London Conference on Illegal Wildlife Trade. (See endwildlifetrafficking.org for further details on the coalition's latest achievements). These recent developments are a vital step forward. However, further vigilance and continued efforts are required as illegal traders adapt their own approaches and attempt to circumnavigate these countermeasures.

To date, guidelines and policies, as well as their translation into action, have overwhelmingly focused on trade in animal-based products[23, 48]. For example, the UK policies of one well-known online auction site relating to the sale of animal and plant products do not appear to be similarly well developed. The animal policy provides considerably more detail regarding CITES and restrictions over international shipping of Appendix II species, and states that the aims of the policy include the protection of endangered species. By contrast, the plant policy only vaguely states that the sale of 'endangered plants' is prohibited (what constitutes an endangered species is open to debate – see Topic Box 2), and directs users interested in 'other' plants and seeds to government website resources, to see whether an item is restricted or prohibited. The stated rationale of the plant policy relates to plant health and the risk of spreading pests and disease, with no mention of the threat to wild populations posed by the sale of illegally harvested specimens. Another major trading platform explicitly references animals but makes no reference to plants within its rules concerning 'endangered or threatened wildlife products'. Numerous other examples abound.

Arguably, such policies fail to reinforce the need for transparent online sales practices relating to regulated plant products, and do not offer potential buyers sufficient information on the type of items to treat with suspicion or avoid. A considerable disparity therefore appears to exist in the efforts of some technology companies to counter the illegal sale of plants across their platforms. Following the progress that has been made in protecting endangered animals, addressing this gap may represent a logical next step forward.

TOPIC BOX 8: PLANT BLINDNESS: ADDRESSING THE ELEPHANT IN THE ROOM

Consider the image below – what do you see? If you thought it was a pair of elephants, you are correct – this is not a trick question. But how much attention did you pay to the baobab tree that has been stripped of its bark?

The researchers Wandersee and Schussler coined the term 'plant blindness' in 1999. It describes the bias towards animals, and general taking-for-granted of plants apparent in many societies around the world[71]. This manifests in a variety of ways, such as considering plants as merely a 'backdrop' to life, failure to notice or pay attention to plants, and a lack of understanding about plants' functions and importance [71].

It is thought the psychological reasons behind plant blindness may be rooted in our evolutionary past, when human senses were more attuned to detecting dangerous animals. Cultural factors are also likely to play a role. Animal-orientated societies often place plants low in the pyramid, of the 'hierarchy' of life. Conversely, in plant-affiliated cultures language and cultural practices place greater emphasis on the role and importance of plants, and plants may attain more of an equal footing[72].

International media and other communications, including from governments and conservation organisations, often reinforce this effect by favouring stories and messages relating to iconic animal species. While this may help draw public attention, it may also entrench blinkered views about the nature and priorities of international conservation. The main exception here is timber, probably because of the high economic value of its trade, as well as the visible impact of logging on forested ecosystems[73].

The effects of plant blindness filter through education[71] to academia, policy making and consequently law enforcement. Historically, the award of funding from major donors to study IWT has been heavily skewed towards research involving charismatic animal species. This emphasis may encourage researchers to focus their efforts on these preferences, so perpetuating the cycle.

Encouragingly, some funding bodies previously focused on animals are now broadening their criteria to embrace plant conservation. These include the Economic and Social Research Council, who funded the FloraGuard project. The IWT Challenge Fund, funded by the UK's Department for International Development, also expanded its criteria in 2018 to include plant-related projects. Such boosts to research capacity are a significant advance, which help bring into focus the threat to biodiversity caused by the illegal trade in plants[73].

4. Addressing the challenge – an interdisciplinary approach


London Conference
Illegal Wildlif
11-12 October 2018
lifeCrime

4.1 Insights from criminology

Law enforcement officers with
a vehicle containing plant material

Tackling environmental crime requires an understanding of its effects upon the environment and the human behaviours and socio-economic conditions that drive it. Criminology can help by offering insights into behavioural and sociological aspects of IWT. Over the last decade, analysis of 'green crimes' has lagged behind other forms of crime – but this is beginning to change.

By breaking wildlife crimes down into their component parts, criminological techniques enable the exploration of the conditions that may lead to criminal acts. Despite its potential value, sourcing information for such criminological analyses remains challenging. Investigative transcripts, judicial material, media and unpublished articles can all yield useful material but a general lack of reporting and low number of prosecutions, particularly for plant crime, limits available data[10, 74].

Internet-facilitated IWT offers new opportunities to apply criminology to the study of the suspected illegal wildlife trade, without the need for crimes to first be prosecuted. Online data can be analysed using criminological techniques to gain insights into the motivations and characteristics of illegal wildlife traders, and the nature of the cyber-hotspots where they operate (see Topic Boxes 6 and 7). Since gathering relevant data from the internet requires sifting vast sums of material, specially crafted digital detectives are needed.

4.2 Digital tools and the role of AI

The biggest challenge involved in combating internet-facilitated IWT is finding relevant data within the mountain of online content. Manual searches are unsuitable for systematic monitoring of the internet, as they are time consuming and labour-intensive. This difficulty is exacerbated by the elusive nature of online criminal activity, which is often characterised by a small amount of user-generated content such as forum posts, hidden within the within the 'long-tail' of busy online platforms.

Getting to grips with the long-tail

The long-tail is an artefact of search demand curves – as keyword terms become more specific and detailed, the number of search results decreases and their relevance increases. Therefore, the use of highly specific search criteria provides both short-term and long-term benefits by reducing the volume of material that needs to be analysed and producing more relevant results.

In many cases a small handful of posts, easily overlooked within the mountain of legitimate online content, may hold important clues[1]. So to prevent illegal trade in wildlife from hiding in plain sight, a method of efficiently, systematically and reliably extracting this evidence is needed[75].

Developments in computer science are improving the gathering and processing of relevant online information but there is no universal or gold standard approach to draw upon. Each situation requires a bespoke combination of tools, tailored to the specific content and type of analysis required.

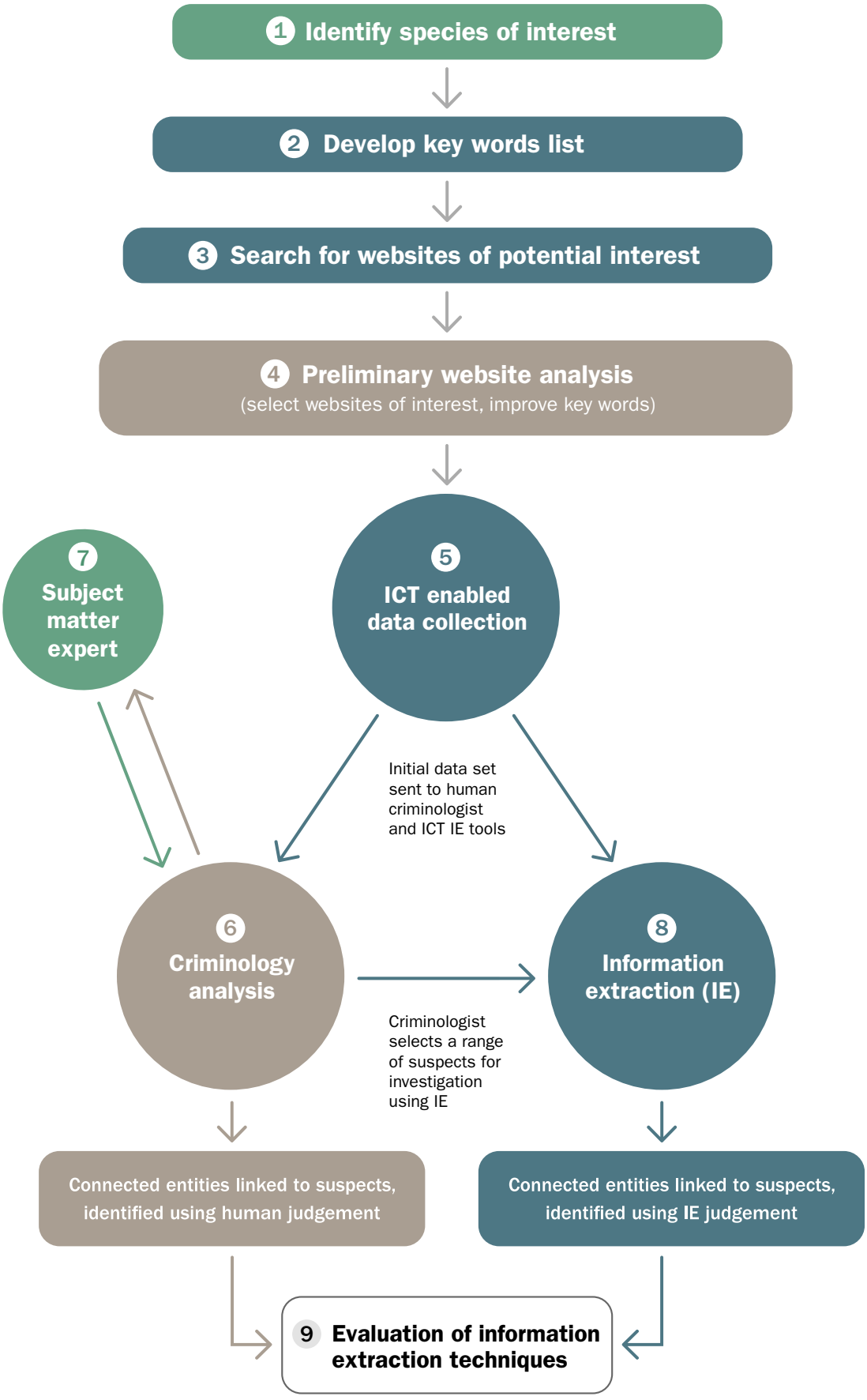
AI, which includes the use of algorithm-based processes, forms the basis for the next generation of online data gathering tools. Automating aspects of data collection can provide researchers with large datasets in a time-effective way. This does not, however, solve the challenge of extracting useful information from large and potentially unwieldy datasets. A 2019 study made use of a combination of web scraping, machine learning and data visualisation tools to investigate the online trade in orchids, pangolins and ivory. Although 'noise' remaining within the data hampered the fine-grained analysis required to disentangle legal from illegal trade, valuable insights into the scale of online trading involving these species were produced[75].

Further advances are needed to convert such data gathering techniques into intelligence products that might enable a range of interventions directly targeting the activities of illegal traders. Therefore, selecting and assessing Information and Communications Technology (ICT) tools and cohering them into a practical toolset was central to the developing the FloraGuard methodology.

5. Methodology – developing a new interdisciplinary approach

FIGURE 1:

Methodology employed during the FloraGuard case-study investigations.



Developing a new data gathering workflow required combining, testing and refining of a number of different digital tools and input sources. The interdisciplinary approach incorporated inputs from subject matter experts in IT, criminology, law enforcement, botanical science and horticulture.

No one group or person had all the knowledge required to collate, process and assess the data.

The selected digital data gathering and analysis tools needed to be individually effective and complementary to one another for the online data to be processed fluidly. To explore their strengths and weaknesses, the performance of the methodology was evaluated in a variety of scenarios involving a range of different websites, species and traded products that might be encountered during a real investigation. Data was gathered during two case study investigations, performed in October 2019 and January 2020.

Each individual stage is described in more detail in the following sections, which correspond to the numbered stages outlined in Figure 1.

1 Identify species of interest

The selection of the target species believed to be potentially involved in illegal online trade was initially guided by semi-structured interviews with 15 conservation and law enforcement experts. These provided the team with insights into the identity of plant species that may be traded illegally online, and the characteristics of the marketplaces and typical actors that may be involved (see [74] for a full analysis of these interviews). A shortlist of species was then selected by a literature review and consultations with conservation experts at the Royal Botanic Gardens, Kew and law enforcement experts from the UK Border Force CITES team. Three plant groups were then selected for use in the study:

- ***Ariocarpus* species:** Seven species (and subspecies) of cacti from the north Mexican highlands and Texas, which are traded mainly as live plants and seeds for the horticultural trade.
- ***Euphorbia* species:** Thirteen species of succulent *Euphorbia*, endemic to islands including Madagascar, the Azores and Canary Islands. These species are traded primarily as live plants and seeds for horticultural trade.
- ***Saussurea costus*:** A perennial herb originating from India and Pakistan and traded mainly as roots and derivatives for medicinal use.

Each of these plant groups met the following criteria:

- The species are a priority for conservation science, due to the threatened status of many wild populations (the majority are CITES Appendix I species).
- The species are popular in trade, theoretically facilitated by artificially propagated specimens, with the trade in wild-sourced specimens highly restricted by CITES.
- The species are traded for a variety of purposes, enabling multiple scenarios including trade in both live plants and derivatives to be investigated.

It was also important to consider the types of trade of interest to the study. As a large number of search results were anticipated for *Ariocarpus* species, seeds were excluded from the search criteria. As the *Euphorbia* species appeared likely to generate fewer search results, seeds were included within the search criteria to help ensure a sufficient number of results.

Appendix A provides a more detailed profile of the selected species, along with an overview of their international trade as recorded in the CITES trade database.

2 Develop keywords list

A selection of keywords specific to each species was required to direct the digital search tools. These included valid Latin names, Latin synonyms and common vernacular names often used in trading situations. This selection was initially generated by conservation scientists, with additional market-related vocabulary added following preliminary online searches (stage 3 below). In some cases, certain words were blacklisted, to either exclude product types that were not of interest, or that were likely to generate a large number of false positive results. A selection of predicate terms indicative of certain types of behaviour (for example, the behaviour 'buying' may be indicated by the words: buy, order, purchase, shop, bought) were then added. This combination of species-specific words, marketplace terms and behavioural words is termed a 'specialist lexicon'. The specialist lexicons generated by the study are reproduced in Appendix B.

3 Search for websites of potential interest

Keyword internet searches were performed using the Bing search engine. Bing was chosen because, at the time of writing, its free account does not restrict the search results as severely as Google's free account in terms of the number of results per search or the maximum number of searches per day.

While internet-facilitated IWT is known to occur in a multitude of languages, English language websites accessible from within the UK were selected. English remains common to many wildlife trading networks and countries in Europe, including the United Kingdom, are among the top global wildlife importers (by value), and are thought to act as a transit hub for trafficking to other regions[76, 77].

4 Preliminary website analysis

The search results were manually browsed by the criminologist to identify websites of potential interest. For the purposes of the study, the focus was restricted to online forums and marketplaces. These open access platforms offered a source of data which could be gathered ethically and avoided the closed nature of social media platforms, where conversations conducted in private are not readily accessible to researchers. In line with the ethical requirements of the study (University of Southampton approvals ERGO/FPSE/41260 and ERGO/FPSE/46393), the search tools were deployed using a strict policy of passive crawling. For sites that did not allow crawling in their terms and conditions, use was only made of public pages discovered by search engines without using a forum login. This also replicates real-world scenarios, as many law enforcement agencies working on IWT only have legal permission to consider what is available to them through

Anti-poaching operations

the open web pages, unless they obtain separate authority such as a search warrant (for further details, see [90]). Table 2 shows the websites selected after this initial phase of research and analysis.

TABLE 2:

Overview of forums and marketplaces selected for the case study investigations

Forum	Species group	Focus	Country of origin*
I	*Ariocarpus* spp.	Horticulture	UK
II	*Ariocarpus* spp.	Horticulture	UK
III	*Ariocarpus* spp.	Horticulture	US
IV	*Ariocarpus* spp.	Entheogens**	AUS
V	*Ariocarpus* spp.	Entheogens**	US
VI	*Euphorbia* spp.	Horticulture	UK
Marketplace			
Etsy	*S. costus*	Health-related products	Multinational
eBay	*S. costus*	Health-related products	Multinational
Alibaba	*S. costus*	Health-related products	Multinational

* Each forum was based in a particular country, although in each case their user-base was international.

** These websites were associated with drug use and are discussed within the Results (section 6).

5 ICT-enabled data collection

Datasets were gathered from the selected websites in a two-stage process:

Web crawling

Web crawling involves downloading large volumes of online content. In this case, the content of interest was relevant posts and threads in marketplaces and discussion forums. To achieve this, the team employed the DARPA Memex undercrawler. This open-source command-line software can perform multiple searches and handle pagination – tasks that are difficult for traditional web crawlers. This did, however, restrict its use to websites with a paging feature, which made them searchable. Where forum terms and conditions permitted crawling, forum accounts were created for the undercrawler to use. Otherwise, crawling was restricted to the public pages returned by the Bing searches. Web crawling was performed as an overnight process, with download throughput restrictions imposed (e.g. 1 page every 15 seconds) so crawling did not negatively interfere with any websites. The crawler worked by downloading all of the pages within a forum thread, before applying a relevance filter to store only those that contain phrases relating to the keywords list. The downloads were stored as HTML files, (these contain the web pages' text and metadata), along with links to any images displayed by the web page. Further processing was then required to extract key content for further analysis.

Parsing

Parsing is the process by which key information is 'read' and extracted from an HTML dataset. The Python Standard HTML Parser Library was selected to search for content relating to the keywords list from within the data extracted by the undercrawler. The final output for each parsed forum was stored as JSON files containing the sentences and metadata (such as author name and timestamp) of relevant forum threads and posts. The rest of the data was discarded. The following are pseudonymised excerpts of an example JSON file, in which names and identifying information have been changed:

```
{
  "threads": [
    {
      "pages": [
        {
          "replies": [
```

```
            {
              "id": "123123",
              "author": "Marcus",
              "date": "2010-06-16 16:45:00",
              "content": "What fantastic plants Mary,
thanks for the pictures. I'm haven't any [species
of Euphorbia], but I would like one! How do the
grow in the summer?  The Meduse is gorgeous too,
beautiful flowers.  ",
              "title": "Euphorbia plant collection",
"images": ["forum.XXXXX/images/XXXXXXX.gif"]
```

```
            {
              "id": "135135",
              "author": "Mary",
              "date": "2010-06-18 16:45:00 09:30:00",
              "content": "Hi, thanks for your messages
about the photos [http://XXXXXXXXXXXX/
albums/XXXXXXX.jpg]. Marcus, I got 40 [species
of Euphorbia] last year. It grows very slowly here
in [specific country], but flowers when very hot
(40 degrees+). Rebecca – for [another species
of Euphorbia] I have only 6 plants from last year,
although I also now hove over 20 of my own plants
from seed.
              "title": " Euphorbia plant collection "
```

6 & 7 Criminological analysis / subject matter expert inputs

Spreadsheets of parsed data were passed to the criminologist for manual analysis. The data was explored to identify suspects who may be involved in illegal trade, along with any posts, profiles and external sites referred to within their own online posts relating to three main areas of interest. First, posts with information regarding potentially illegal trades (e.g. specific cases reported, countries involved, central actors involved, and how these trades were perceived by the forum users). Second, posts related to CITES permits and how these were framed by forum members in broader debates of species conservation. Third, posts related to relevant subcultural factors. The subsets of relevant posts were coded according to a framework developed over the course of the study, using the software package NVivo.

TABLE 3:

Coding framework developed for manual criminology analysis

Code	Sub-code
User role	Vendor; customer or potential customer; user giving feedback or expert advice
Selling mechanism	Auction offline; auction online; barter; buy-it-now; forum; gift; local vendor offline; nursery offline; nursery online or specialised website; order; show
Selling type	One-off trade; sale of bulk trade items; relationship seller-buyer continues over time.
Payment method	Bank transfer; cash-in-hand; PayPal; not specified
Payment type	Fixed price; price varies
Location of the product	Country of origin; country of trade; product exchange location
Mention or discussion of permits	CITES; criticism of CITES; CITES enforcement; phytosanitary permit; national legislation; caveat emptor
Social interaction type	Advert; expression of interest; feedback on trade; explicit discussions about potential illegality; discussions about how to avoid controls or minimise risk in illegal trade; references to offline interaction; testing the ground
Other	Product of unknown origin; Brexit; politics; motivation; eBay enforcement; online vigilantism; conservation

As each case study investigation unfolded, specific data requiring interpretation from conservation scientists was sent to the Royal Botanic Gardens, Kew for assessment. This included evaluation of online plant images and the interpretation of specific terms (e.g. use of the word 'habitat' in different contexts). During the course of the analysis, the criminologist identified a selection of four to five suspects for each of the three plant groups. These were then used as a ground truth dataset, against which the performance of two types of information extraction software could be measured.

8 Information extraction

To detect content within the parsed files that was both relevant to the keywords and indicative of suspect behaviour, a more sophisticated method of information extraction was required. This tool would need to analyse content around target suspects and identify the relevant locations, people, plant species and organisations ('entities') discussed. From a wide range of techniques previously employed within online criminology investigations, two were selected for testing and comparison.

These techniques were topic modelling and named entity (NE) directed graph visualisation, information extraction techniques which fall under the natural language processing class of algorithm. Information extraction involves automatically extracting structured information from unstructured free text documents, such as the datasets of posts crawled and parsed discussed in the previous section. Free text posts are pre-processed to automatically label named entity phrases. Keyword filtering is then applied so that only posts containing named entities relevant to the current search objectives are kept.

Topic modelling using Latent Dirichlet Allocation

Topic models aim to identify clusters of words associated with set topics occurring in, for instance, online forums or social media conversation threads. In recent years, a wide range of these clustering approaches have been applied to the analysis of criminal activity. For cybercrime applications, the model known as Latent Dirichlet Allocation (LDA) has received particular attention, and has been used to classify crime incidents, generate topics for discourse analysis and to explain community level activity.

To run the topic model, each forum was first filtered to remove any irrelevant threads that did not contain a single post with the target suspect mentioned. Posts within the remaining threads were then processed in their entirety. All sentences, including those not containing keywords, were captured, so that the context around a keyword could be explored. A sentence corpus (a structured set of text) was then created by aggregating all relevant thread posts containing one-word and two-word phrases (e.g. *Ariocarpus*, rare *Ariocarpus*). A filter was applied to remove very common phrases with greater than 95% document frequency and very uncommon phrases occurring less than twice. An LDA topic model was then computed, displaying the ten most relevant topics, with each topic containing a set of 20 phrases. These phrase

lists were then viewed manually to find correlations between suspects and other entities. The top 20 phrases were taken for each topic, since larger phrase sets (e.g. 100 phrases per topic) would be too time consuming for a criminologist to work through. An example topic model generated by the study is discussed in the Results (section 6).

Named entity recognition and directed graph visualisation

Graph visualisation aims to generate small directed graphs of connected entities, with the target suspect presented as the root node within a network style diagram. To some degree, this technique automates the approach used in criminological analysis, where suspects are first identified and posts are then analysed to see connections and exhibited behaviours.

To perform named entity recognition, all forum posts (relevant or not) were collated and their sentences labelled using a grammatical analysis tool (Stanford CoreNLP toolkit, stanfordnlp.github.io/CoreNLP). The named entity labels were then filtered to remove those less relevant (e.g. religion). Threads and posts mentioning the remaining named entities were then indexed and listed. Authors, threads and posts were then added as additional entities. The connection between each named entity and its post identifier was retained, to avoid jumps from one post to a completely unconnected post which happened to also mention the same entity. Suspects' graphs were then visualised using Matplotlib (matplotlib.org) and NetworkX (networkx.github.io) visualisation software, so that connections between suspects could be observed and interpreted by the criminologist. Example graphs and their analysis are detailed in the Results (section 6).

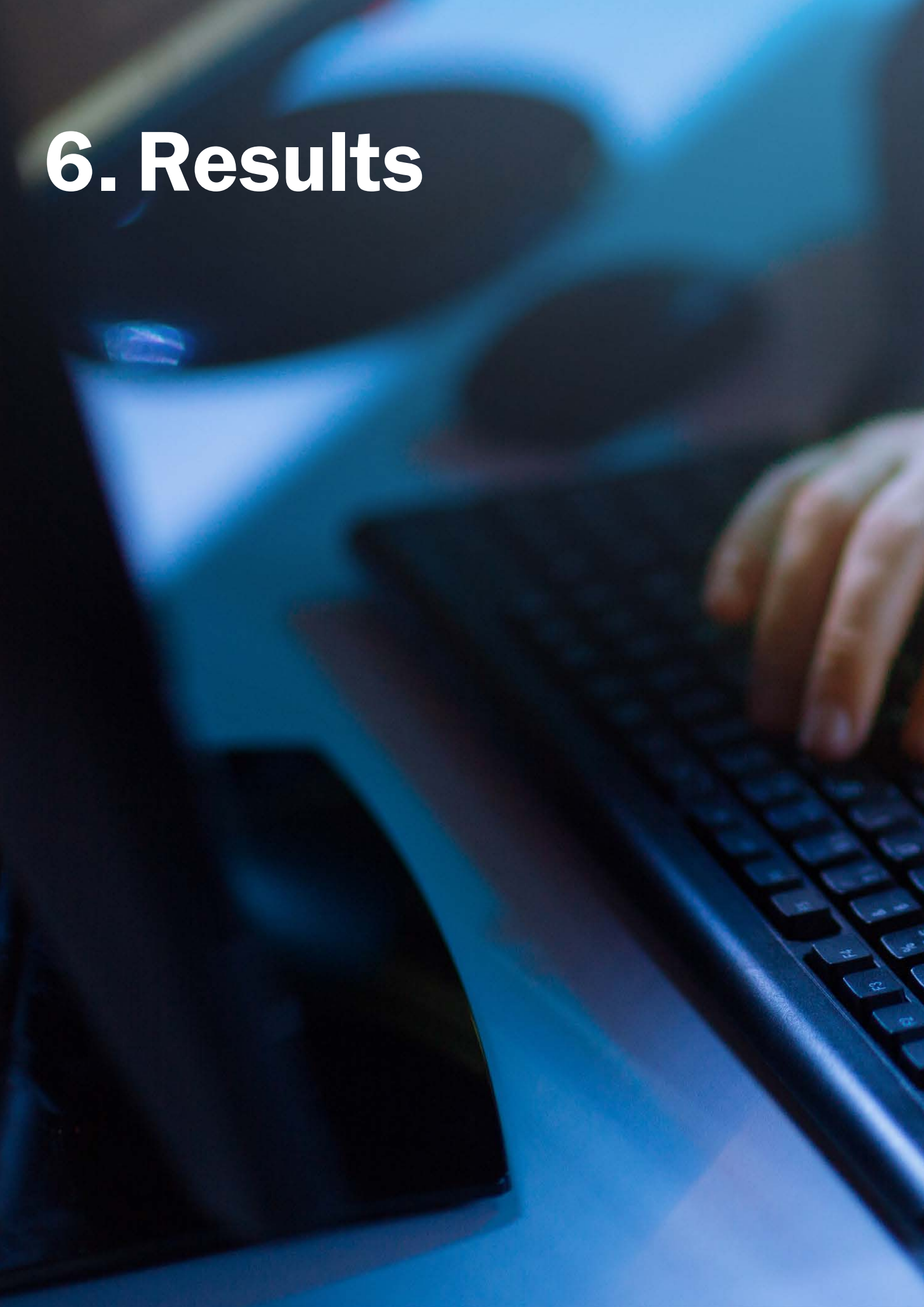
9 Evaluation of information extraction techniques

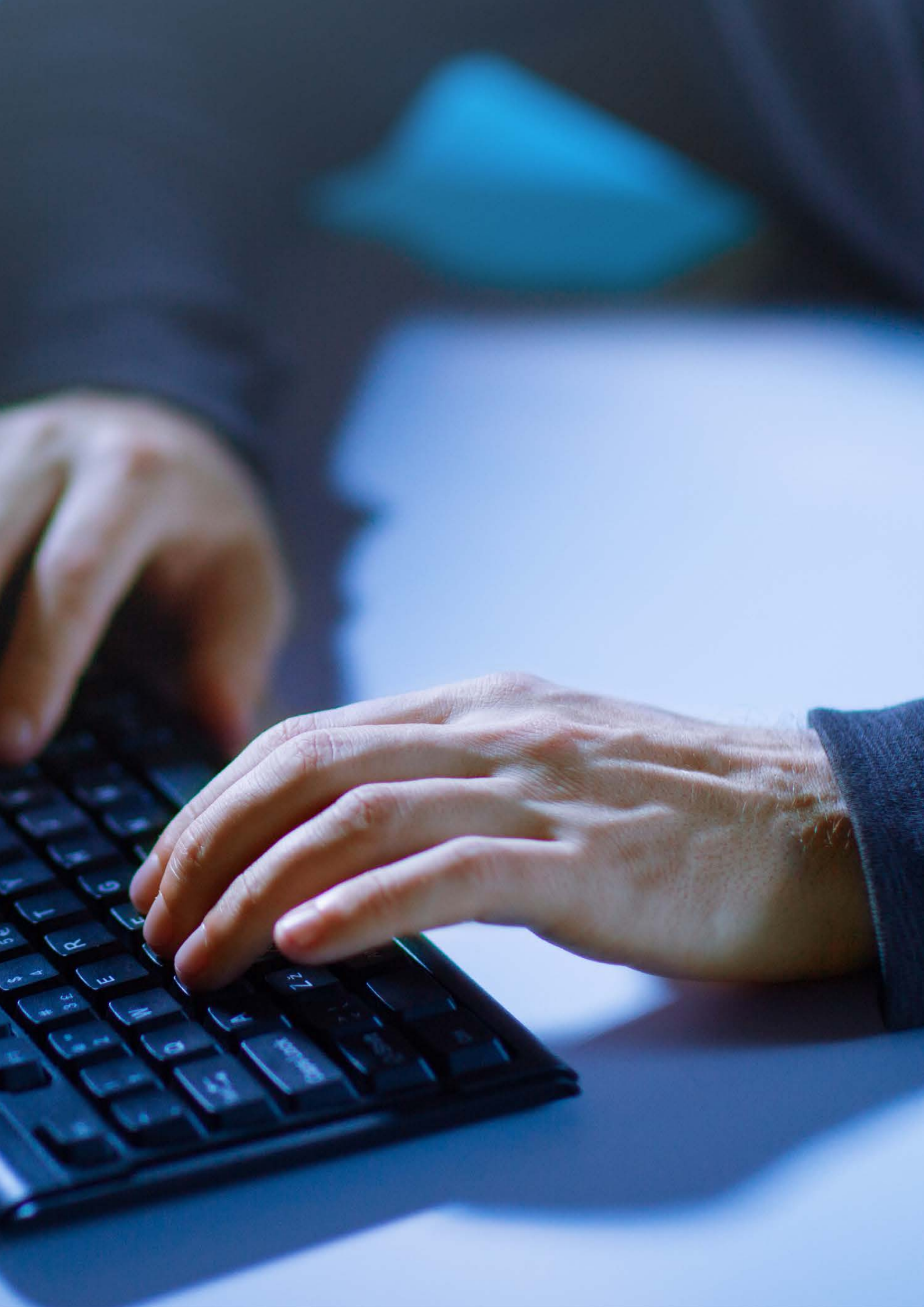
To measure the performance of both information extraction techniques, the number of relevant entities connected to each suspect identified by each technique was compared with those identified by the criminologist. This comparison is discussed within the Results (section 6).

For a more detailed overview of the methodology and techniques employed, see: [1].

Ariocarpus trigonus

6. Results





Euphorbia handiensis

We evaluated our approach using two case study experiments, each based on a one-week criminology investigation (aided by conservation science experts) of forums and marketplaces around cases of potentially illegal traded *Ariocarpus* species, *Euphorbia* species and *Saussurea costus*. This allowed different approaches to data extraction and analysis to be measured and evaluated across a range of scenarios.

The study also generated specific insights into the use and trade of each of the three plant groups, within both online forum and marketplace settings.

6.1 Performance of the methodology

To evaluate the methodology both the efficiency of data gathering and the accuracy of data processing and analysis were considered.

Efficiency of data gathering

The technique proved capable of capturing large amounts of data from within busy forum and auction websites. For instance, in one of the searches performed, the crawler was able to search more than 600 forum threads, spread across 2,500 web pages and containing more than 1.5 million words.

In total, more than 68,998 posts were crawled. Within this content, 13,697 posts from 4,009 authors were identified as containing potentially relevant information. Manual analysis of these posts by the criminologist identified a subset of relevant posts, annotated with target suspects and connected entities, totalling: 543 posts for *Ariocarpus* species, 768 posts for *Euphorbia* species and 947 posts for *Saussurea costus* (20 on Etsy, 695 on eBay and 232 on Alibaba). Identifying these subsets took the criminologist around 25 hours per plant group. Table 4 displays a breakdown of this data.

Accuracy of information extraction tools

The performances of the two information extraction techniques (LDA topic modelling and NE directed graph visualisation) were measured against a set of ground truth data prepared by the criminologist. This consisted of a set of entities which the criminologist deemed to be connected to the 4–5 suspects identified for each of the plant groups during the case study tests. The 'recall' of each information extraction technique was then tested against these results. Recall is defined as the fraction of ground truth connected entities (entities found by the criminologist and manually tagged as connected to the target suspect) which appear in the outputs of each information extraction technique.

TABLE 4:

Overview of the dataset generated by the two case study investigations

Species group	Websites	Authors	Threads	Total crawled posts	Crawled posts with relevant keywords manually browsed by criminologist	Subset of posts identified as relevant by criminologist
***Ariocarpus* spp.**	5	3,308	1,281	52,217	9,676	543
***Euphorbia* spp.**	1	545	545	15,518	3,733	768
Saussurea costus	3	156	N/A	1,263	288	947*
Total	**9**	**4,009**	**1,826**	**68,998**	**13,697**	**2,258**

* The subset of data for *Saussurea costus* increased due to the criminologist adding adverts from the website and elsewhere. The machine-led approach only considered the main auction website posts and did not always consider the profiles or replies that were contained within them.

For example, if the criminology analysis finds ten people connected to a target suspect, and information extraction shows five people from its list, then the recall is 5/10, expressed as 0.5. The mean recall for all target suspects in the ground truth data was then calculated (Table 5).

TABLE 5:

Mean recall of the two IE techniques. A recall of 1.0 would mean that IE had discovered every entity identified by the manual criminological analysis. People and organisations were not readily identified for *Saussurea costus* posts, as this information was less easy to extract from auction site advertisements that related to this species.

		Mean recall			
Connection type	**Model type**	***Ariocarpus***	***Euphorbia***	***Saussurea***	**All**
People	Topic model	0.00	0.27		0.14
	NE graph	0.34	0.78		0.56
Location	Topic model	0.00	0.00	0.00	0.00
	NE graph	0.56	1.00	1.00	0.85
Plant species	Topic model	0.05	0.24	0.00	0.10
	NE graph	0.20	0.40	0.14	0.25
Organisation	Topic model	0.00	0.00		0.00
	NE graph	0.33	0.14		0.24

The mean recall scores indicated that NE directed graph visualisation performed consistently better than the LDA topic model in identifying connected entities of potential interest. While neither technique was as precise as the criminologist, the NE directed graph visualisation software was accurate enough to suggest that it would offer a useful enhancement to criminological analysis in a real-world setting. This includes its potential to speed up the search and analysis process, reducing the time required for the criminologist to access and evaluate relevant data.

The low, and in some cases incomplete, recall of the information extraction tools for the *Saussurea costus* auction sites was due to the criminologist delving further into the links contained within these posts (and therefore processing a higher volume of raw data) than the information extraction tools were readily able to access. Further manual preparation of these links to provide the information extraction tools with greater access to their contents may have improved these recall scores. This highlights the need for the bespoke handling of different sources of online data, as they do not all respond to investigative tools in precisely the same way.

Visualising and interpreting the data

Visualisations of the data generated by information extraction techniques are useful to human analysts, as they show the connections discovered between entities. Establishing the ease in which visualisations produced by the two information extraction techniques could be interpreted for the purposes of a wildlife crime investigation was therefore crucial to developing and refining the methodology. The following summaries provide an overview of the visualisations generated by each technique.

LDA topic model

The topic model outputs are phrase lists, which enable correlations between suspects and other entities to be made. The 20 most commonly occurring phrases for each topic were selected, as described in the Methodology (section 5). A pseudonymised example, in which all names of people and organisations have been changed, is given below:

Examples of phrase lists generated for *Ariocarpus* species

“topic_1”: [“greenfingers123”, “Ariocarpus”, “seeds”, “Here”, “http www”, “www”, “old”, “picture”, “http”, “years”, “markthegardener”, “Dino54”, “retusus”, “list”, “This”, “10”, “eBay”, “Ariocarpus retusus”, “greenfingers123 Here”, “Smith”]

“topic_2”: [“cacti”, “And”, “satin”, “crash satin”, “crash”, “like”, “Cactisaurus”, “looks”, “probably”, “greenfingers123”, “ Plantnursery”, “cacti”, “sell”, “legal”, “good”, “looks like”, “seeds”, “hybrid”, “live”, “bought”]

In the above example, the suspect ‘greenfingers123’ has been mentioned in association with a number of other entities including people (e.g. ‘markthegardener’, ‘Smith’, ‘Dino54’), organisations (e.g. ‘Plantnursery’) and platforms (e.g. ‘eBay’).

In order to process the data for each suspect, an analyst would need to examine possible connections over at least 20 sets of topic phrases.

Named entity recognition and directed graph visualisation

As described in the Methodology (section 5), graph visualisation generates small directed graphs of connected entities, with the target suspect presented as the root node within a network style

FIGURE 2:

NE directed graphs for a species of *Ariocarpus*, with one depth connection (above) and two depth connections (below). Target suspects are coloured green, posts (with author names removed) and threads grey, predicates yellow, locations purple and people blue. The real names and organisations have been pseudonymised.

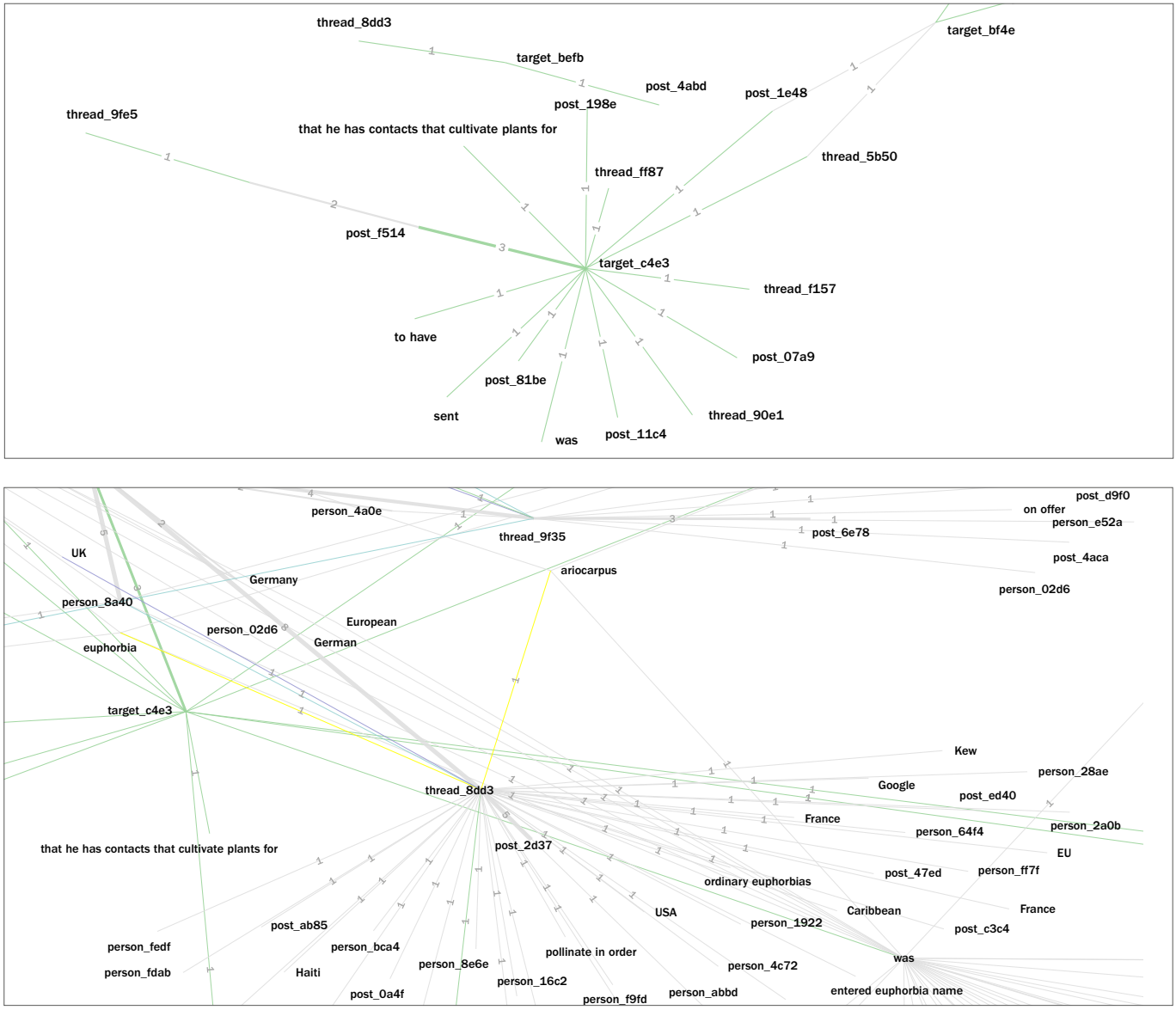


diagram. By adding relevant entities around each suspect, and then searching for further entities that are linked to them, the 'depth' of the graph can be increased.

The graphs can be analysed by performing 'graph walks'. Starting from the target suspect's node chains, connected entities can be followed one, two or three levels deep. As connections are discovered, new entities of interest can be used as new root nodes for the next level's graph walk. This enables investigators to switch focus as necessary, for example from an individual to an organisation. Walks can find connections in a forward direction (e.g. thread A contains post B, post B mentions entity C) and a backward direction (e.g. entity C was mentioned by post B). As the graphs represent sequences of entities as they appear within a forum thread, the analyst views sets of posts talking about the same thing in conversational sequence.

The number of entities in each graph ranged from tens to more than 400 depending on the target species and suspect. To help interpret graphs containing hundreds of entities, nodes were colour-coded by entity type. As the visualisations are interactive they can be zoomed into and panned around to explore dense data more easily. Crucially the graphs retain links to the original posts, enabling any police investigation follow-up that may be required.

For full details of the NE graph construction and performance see [1].

The FloraGuard NE directed graph visualisation code is released as open source, and is available at:

https://github.com/stuartemiddleton/intel_viz_entity_graph

6.2 Qualitative insights in the internet-facilitated illegal trade in plants

Data was gathered from nine different websites: six forums which offered insights into the trade of *Ariocarpus* and *Euphorbia* specimens, and three online marketplaces which dealt with trade in *Saussurea costus* derivative-based products.

Of the 13,697 posts identified by the web crawler as potentially relevant to trade in the three selected plant groups, 2,258 (16.5%) were selected by the criminologist as being of potential relevance. That the vast majority of horticultural forum posts were discarded is unsurprising, as these websites are primarily used for the sharing of legitimate information – for instance on cultivation, plant-related events or photographs. It was clear that these online communities were friendly environments and open to new members. Most forum users genuinely enjoy the slow (but rewarding) process of plant cultivation, and do not seem interested in pursuing illegal activities. The data analysis therefore focused on the far less frequent exceptions to these legitimate practices.

A qualitative criminological analysis of the subset of posts relevant to online trade in these species was then performed. The following sections summarise the key findings of this analysis. As many observations were broadly applicable to trade within these online settings, for simplicity results are presented at genus level. This is sufficient to illustrate the potential of this approach to inform research and investigations, although the scope of the analysis could be narrowed to individual species wherever this level of focus is required.

Online trade in live specimens

Trade in live specimens of selected *Ariocarpus* and *Euphorbia* species was examined within six online forums. Four of these related to horticulture, while two concerned naturally occurring entheogens, the term used to describe the use of fauna, flora and fungi species with psychoactive properties in cultural, religious, shamanic or spiritual contexts (see Topic Box 10). Certain species of cacti are known to contain psychoactive alkaloids such as mescaline, including *Lophophora williamsii*, a small spineless cactus commonly known as *peyote,* which shares a similar range to *Ariocarpus* species in Mexico and Texas. This may help to explain the interest in *Ariocarpus* species, which may be thought by some to contain similar properties. One of the entheogenic forums contained links to a web store selling a variety of products including plants and seeds. Elsewhere, references to trade within forums either involved mentions of e-commerce platforms, or were implied as potentially taking place through less formal arrangements.

While the underlying motives of these horticultural and entheogenic online communities differ, the mechanisms involved in trade in CITES-listed plants frequently overlap. For the purposes of this analysis, insights from these two interest groups are therefore considered together.

i. Trading patterns and platforms

Expressions of interest in *Ariocarpus* specimens ('conversation starters') were identified in seven different posts in which forum users sought to either purchase specimens or barter them for other plants. Similar interest in *Euphorbia* specimens was identified in three additional posts. Examples include a user seeking *Ariocarpus* who was prepared to offer other species (a full list was provided) in return. Most *Ariocarpus* specimens appeared to be one-offs, although buyers may also have ongoing relationships with certain sellers, nurseries and websites, and may recommend these outlets to other forum users. In some cases, the possibility of bulk sales was also discussed. For example, in posts relating to *Euphorbia* species, it was suggested that international traders (selling via eBay or through specialised online/physical shops) buy from the country of origin in bulk quantities, before selling on to individual buyers.

These online forums also contained links to external marketplaces, and discussion frequently referenced the market value of certain species. While some forum members enjoyed the excitement of auction bidding (one poster compared it to playing poker), others avoided auction sites believing that they lead to inflated prices. While some (particularly more experienced) forum members considered auction sites a last resort for buying, some sellers saw them as a useful sales platform, or a means of 'testing' the price of unusual specimens they intended to sell. In some cases (in this instance, linked to the trade in *Euphorbia* specimens), members indicated they use more specialist auction sites with restricted access to avoid 'timewasters' and 'troublemakers'. Other specialised websites relating to offline nurseries and international shows were also regularly mentioned as go-to places for trade, particularly for *Euphorbia* specimens.

There was also evidence of some sellers manipulating sales platforms to their advantage. This includes the practice of 'keyword spamming', where other less sought after but still high-end cacti (such as peyote) are advertised using the terms *'Ariocarpus'* or 'no-*Ariocarpus'* to give their products more visibility. It was recognised by forum users that this practice is against eBay's rules, but also that those rules are hard to enforce. Online discussions also revealed that alternative species may be mis-sold as *Ariocarpus*, to fool non-expert buyers into paying more. The prevalent view seemed to be that it is the buyer's responsibility to be better informed about their purchase. Overall, cyberspace was widely recognised as the major facilitator providing buyers with access to hard-to-get species, with one forum user calling the internet 'wonderful'.

ii. Forum member profiles

Users of these forums were broadly divided into specialist collectors and less knowledgeable hobbyists. Here, a type of 'us versus them' rhetoric was identified: for example, specialist collectors showed a preference for specialised marketplaces and sometimes referred to less experienced buyers who use eBay as 'gullible', 'idiots', 'newbies', or 'common people', at risk of overpaying for their plants. Specialists pursuing legal trade often appeared to enjoy

Lophophora williamsii

growing specimens from seed and distanced themselves from those ready to buy illegal specimens because they were in a hurry to obtain a mature plant.

iii. Plant provenance

The origin of plants at the centre of online discussions was often unclear, even to forum users, and mature plants were often referred to or advertised without acknowledgement of their origin or legal status. In some cases, opinions were sought on the apparent age/size of a specimen or its online description, and whether these may be indicative of wild sourcing. The images of plants within some posts also generated discussion (see Topic Box 9). Some admitted to having no idea of a plant's origin, other conversations were vague in respect of these details, describing specimens as 'bought […] from you-know-where', or as arriving 'unlabelled'. In one case, an *Ariocarpus* was said to have been 'transplanted from West Texas' to another part of the US before being sold internationally. The origins of *Euphorbia* specimens were equally difficult to determine, with references to nurseries and exporters often vague in detail. In some cases, members commented on the lack of clarity over the origins of some specimens or raised concerns over the high number of rare and difficult to grow species that certain sellers appeared to possess.

iv. Evidence of internet-facilitated IWT

Within the forums analysed, illegality relating to plant trading was discussed relatively openly. Two collectors admitted owning illegally sourced *Ariocarpus*, while others discussed the names of three sellers allegedly selling illegally poached *Ariocarpus* (one of them linked to a nursery), and referenced six nurseries and two European plant shows where they believed they could easily access illegal specimens if they wished. One name was linked to suspicious activities in both the *Ariocarpus* and *Euphorbia* forums.

Within entheogenic forums it appeared that, at times, wild-sourced *Ariocarpus* may have been involved in experiments. Two forum members mentioned they had bought *Ariocarpus* (one from a nursery, another from land that was being cleared for livestock) for 'research' but that they could not feel much effect. One conversation made direct reference to the wild origins of an *Ariocarpus* specimen, while other posts contained suspicious-looking (but inconclusive) images of mature specimens. A light-hearted exchange referred to the possibility of collecting specimens from the desert.

In some cases, forum users were observed exchanging advice on how to conduct illegal imports of specimens via different shipping and postal services. This included the

TOPIC BOX 9: A PICTURE TELLS A THOUSAND WORDS?

Images of live plants within online posts can hold valuable clues to indicate that a specimen may have been removed from the wild, rather than grown in cultivation. For instance, the shape of some species may differ between wild and cultivated settings. This applies to both roots and above ground structures, and wild plants may undergo new flurries of growth as they adapt to the 'comfort' of captive conditions. Other tell-tale signs include insect damage and other blemishes such as wildfire scorch marks, or debris unlikely to be found in a plant nursery may be visible between the plant's structures.

During the course of the study, numerous suspicious images of *Ariocarpus* specimens were found among the sampled posts. Due to the need to anonymise data, these are not reproduced here, but the illustrative examples to the right provide an overview of the type of information that it is sometimes possible to obtain from these posts.

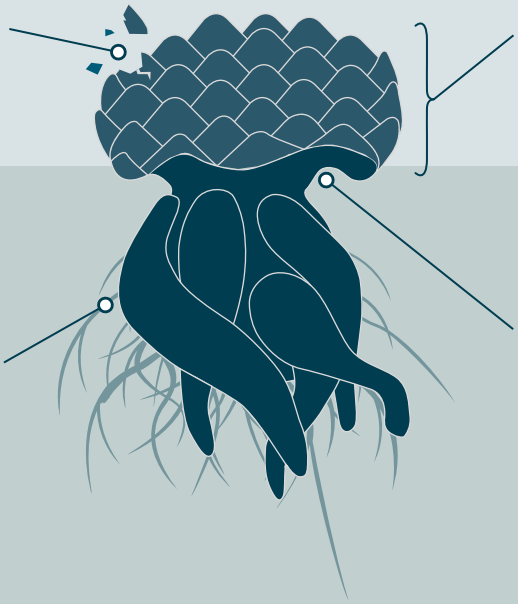
Ariocarpus kotschoubeyanus

PLANT SHAPE

For many species, the 'luxurious' growing conditions provided by cultivation means they assume slightly different shapes to their wild counterparts. Wild specimens of *Ariocarpus* are likely to be 'flatter' in appearance, with more densely packed tubercules, compared to more voluminous home-grown plants. The images to the left are of two specimens which are housed at Kew. The one on the left is a wild-sourced *Ariocarpus*, which was seized by customs, while the specimen on the right has been cultivated.

BLEMISHES AND DEBRIS

Wild-sourced plants are often marked by blemishes, for instance from insect damage or scorch marks from wildfires. Debris that would not be expected within a nursery setting may also collect within the plant's structures.



PLANT SIZE AND AGE

Ariocarpus are very slow-growing species. A large plant of 15–20 cm in diameter may be decades old, and while specimens have been in cultivation for that length of time, this may raise questions about the plant's history, and reasons for the sale at this point in time.

ROOTS

In the wild, roots may grow in unusual shapes as they negotiate subterranean obstructions. Poachers may also cut off the large tap root to help quickly extract the plant, which does not necessarily kill the plant as a result. More fibrous roots may also have been knocked off, although this could also occur during re-potting.

CLEANED UP TUBERCULES

The 'necks' of older *Ariocarpus* are often fringed with a thick layer of tubercules which have died back. In this example, these appear to have been cut off, potentially to help disguise the plant's wild origins. However, cleaning plants up in this way can also be part of good horticultural practice.

ADVERTISEMENT INFORMATION

In some cases, images are accompanied by advertisement information. While not offering conclusive proof, the following typical examples may raise suspicions of potential wild sourcing:

High price tag $$$$$

Country of origin = the native range of the plant in question. For *Ariocarpus*, this would be Mexico or certain regions of the United States.

International shipping offered, with no mention of CITES procedures, and no factoring in of the costs and timeframes involved.

Vague references to customs clearances being 'the buyers responsibility'.

Such photographic evidence is not foolproof, however, and many ambiguities may exist within the image and associated information. Firm identification of species from photographs can also be challenging, particularly for genera which are similar in appearance when not in flower. Images posted online may also be stock photos that do not actually represent the specimens being offered for sale [11].

Nevertheless, such photographs may offer conservation or law enforcement experts a useful source of corroborating evidence in investigations into the poaching of wild plant populations. While many signs of wild-souring are widely applicable, others may be specific to certain genera, so conducting an analysis would require a level of species-specific training and experience. Applying these insights to the training of AI image recognition tools may also hold potential for future investigative work, although the domain-specific image recognition required to identify plant species is not as mature a technology as some commercially driven applications such as facial recognition technology.

misuse of declaration forms to vaguely describe items as 'collectables' or 'garden ornaments'. One sought advice on species names that they could safely declare, in an attempt to fool customs authorities.

Posts by some new forum members appeared to be testing the ground, for instance asking if it was possible to bypass moderators' controls. Two new forum members who had posted pictures of impressive specimens soon disappeared from the conversation when asked how these had been grown. Three apparently new forum members from East Asia were also explicitly accused of trying to sell illegally sourced *Ariocarpus* specimens. These are examples of potential illegal trade that the FloraGuard methodology is adept at discovering by tracing relationships between forum members and tracking where they reappear.

Illegality in offline settings was also discussed. Instances of people travelling through airport customs without declaring goods they were flying with were recounted. One forum user reported bringing plants purchased in Spain into the UK by car without incurring border checks. Overall, the likelihood of being caught with an illegal plant specimen was considered extremely low.

Links to specific countries were also detected. One forum member claimed to know of a case in South Africa where 'habitat-collected' plants were supplied to local nurseries, who passed them off as artificially propagated specimens. Within the EU, Hungary, the Czech Republic and Belgium were suggested as weak links through which illegal imports might be made. Some countries within Asia, including China and Japan, seemed to share a similar reputation.

In some cases, a lack of detail made it difficult to determine the legality of trading arrangements. Within the entheogenic forums, CITES was never explicitly discussed, even where posts discussed the cross-border movement of plants. Examples included a discussion about a potential shipment of *Ariocarpus* from Mexico to Australia, and a forum member requesting information 'for a friend' on moving button cacti from Canada to the United States. Another forum member recalled ordering four specimens of *Ariocarpus* from a European nursery, with the help of others who acted as go-betweens. It is unclear whether this trade was conducted legally or not.

v. Attitudinal insights

Analysis of forum threads provided insights into a range of attitudes and sentiments relevant to the trade in endangered species.

Attitudes towards CITES, law enforcement and illegal trade

While references to CITES were usually absent from discussions concerning the potential shipment of specimens, concepts relating to CITES and other aspects of law enforcement arose frequently. In discussions about permits and regulations, many members provided their own interpretations of the rules, supported by information that was generally inappropriate (for example old blog posts). CITES and CITES-related prosecutions were discussed in imprecise terms, particularly with regard to the appendices and the burden of proof. In some cases, the illegality of certain acts appeared genuinely unclear to some. When discussing eBay policies on wildlife trade, one forum member suggested that breaking CITES rules might be an ethical grey area but did not contravene any laws. Another did not consider wild sourcing to be poaching if there was no intention to sell the specimen. There was also confusion over the status of specimens sent as gifts, and whether CITES applies equally to commercial businesses and private individuals (it does). Only one member of a horticultural forum (who posted in just one thread) seemed able to give precise information about CITES and its relationship with EU regulations.

Some forum members were highly critical of CITES. To some, it was seen as a 'club' of professional zoologists and botanists representing their own interests. Here, a second type of 'us versus them' rhetoric was identified: some more experienced members (perhaps specialist collectors with expertise in certain areas) felt disregarded by those working within professional institutions. Some felt CITES is an ineffective 'smokescreen' used by governments to pretend they care about plant conservation by preventing wild collection (which, according to this view, would have only a minor effect on wild populations), while allowing the destruction of plants during construction work in other locations. One poster, who was very active in two of the forums, was critical of both CITES and EU regulations, perceiving them to be a bureaucracy-driven waste of resources with little utility for conservation. CITES was also considered burdensome, with one forum member, for instance, being resentful of the need to keep administrative records of their plant collection. The high cost of CITES permits to amateurs making small international orders was also noted. Some forum posters also expressed the opinion that CITES may potentially encourage plant crime by limiting the number of specimens available for propagation, thus creating a driver for poaching and illegal trade. The fact that CITES represents an international agreement was also regarded by some as 'undemocratic'.

Harsh criticisms were also directed towards customs confiscations. Two forum members claimed that plants held at customs received inadequate care while waiting to be processed. There were also complaints that confiscated plants are often destroyed (without acknowledging that this is sometimes required to protect plant health and guard against invasive species).

Support for CITES was conspicuously absent from forum posts, although some references suggest that frustrations lie in a perceived lack of effective implementation. Some forum members felt that there was insufficient will to enforce CITES, and that customs did not care about the illegal trade in plants. Another view shared was that there is a lack of political incentive to help CITES fully intervene on conservation matters. Others were critical of the practical aspects of CITES enforcement and the general policing of plant crimes. The challenges faced by enforcement

officers in differentiating wild-collected specimens were also acknowledged. It was also suggested that CITES enforcement agencies should look to specialist societies for assistance, rather than relying solely on official institutions.

Neutralisation techniques

When discussing specimens that may have been obtained illegally, many forum members displayed what criminologists refer to as neutralisation techniques. These are rationalisations that offenders use to justify breaking codes of conduct or deviating from established norms[78]. They have previously been suspected within orchid hobbyist communities, where CITES is sometimes viewed as being bad for conservation[30]. The analysis of forums in the present study identified a range of specific neutralisation techniques within a wide range of conversations relating to the actual or potential illegal sourcing of plants from the wild (Table 6).

TABLE 6:

Examples detected within forum conversations of neutralisation techniques relating to the illegal sourcing of plants from the wild

Neutralisation technique	Examples
Condemning the condemners	In one entheogenic forum, the Mexican government was considered to be very restrictive when authorising the export of native plants or seeds. In another horticultural forum, regulations were described as 'so idiotic' that deliberately contravening them was almost a challenge. Some felt that the historical import of *Euphorbia* species to certain locations legitimised trade in these regions. Attempts by governments to restrict this trade were viewed by some as 'hypocritical', as they considered other forms of human activity to be far more damaging to habitats than the collection of wild specimens. CITES was also often perceived negatively.
Appeal to higher loyalties	In three of the forums some (apparently European) members commented that it is only thanks to poaching in the past that collectors from certain parts of the world can access certain species today. In the Euphorbia forum, it was suggested that without wild collection there would be 'no hobby', and that people from the plants' countries of origin often poach in order to survive.
Denial of injury	Some forum users emphasised that poached plants are bred with care, hence increasing the overall numbers of the species. In areas where construction and infrastructure threaten habitat loss, poached plants may be described as 'rescued specimens'. In one forum, a discussion arose around a paper published in a reputable scientific journal which emphasised the role of the horticultural trade in sometimes worsening the situation for endangered species. This was dismissed by a very active user as 'corrupt science'. In another instance, it was suggested that some level of extinction is 'natural'.
Denial of victim	Some forum users emphasised that (most) cacti removed from the natural habitat are not destroyed.
Denial of responsibility	In one entheogenic forum, a member initially thought that they had bought a grafted specimen (grafting is a technique that joins shoots from the top portion of one plant to the root stock of another) but subsequently discovered that it was a wild-sourced *Ariocarpus*. The buyer claimed that the procurement of the plant was the vendor's responsibility. In a conversation between two *Ariocarpus* forum members, it was suggested that conservation problems may only exist only for a single *Ariocarpus* species (*A. bravoanus*). In a horticultural forum, it was suggested that it can be difficult to know where to draw the line if illegal collection is the only way to acquire a must-have plant.

Pro-conservation attitudes

While some online discourse was rather negative and sceptical in nature, other members of these online communities displayed an awareness of the principles of sustainable use, and of the impacts of illegal collection from the wild. Some forum users distanced themselves from what was at times labelled 'evil cactophile' behaviour. Information relating to conservation was also promoted and shared, with one forum member referring to an article that 'opened their eyes' to the impacts of certain trade practices on endangered species. Within the entheogenic forums, one – albeit more lone voice – expressed environmental concerns, stressing that the cacti being discussed were endangered, and could become extinct if populations are subjected to poaching.

In some cases, forum members actively challenged those they perceived to be exhibiting negative attitudes and behaviours. In a thread in which some forum members were employing neutralisation techniques, others were firm in replying that to destroy a plant in its natural habitat was

Echinopsis pachanoi – one of a number of cacti species containing mescaline, an alkaloid with enthogenic properties

TOPIC BOX 10: PSYCHOACTIVE PLANTS: BLURRING THE LINE BETWEEN DRUG USE AND SPECIES CONSERVATION

Entheogens (derived from Greek, and meaning 'becoming the divine within') are substances with mood-altering effects. They include naturally occurring substances which have been used throughout human history by virtually all cultures for religious, therapeutic and recreational use[79, 80]. Entheogens can have psychedelic, hallucinogenic and deliriant effects. Today, aside from a few exceptions for specific cultural practices, their use is generally forbidden by drug prohibition.

The members of the entheogenic forums examined identified themselves as 'psychonauts' or 'psychedelic researchers' trying to explore altered states of consciousness[81]. While some reported experimenting with substances it was also stressed within the community that it was not a good idea to ingest something without understanding its potential effects. Indeed, the side effects of psychoactive drugs can be very severe[82, 83]. Some forum members were also interested in the potential medicinal properties of some of the plants discussed, which could also be potentially dangerous. One forum member, for instance, held the view that some cacti are more likely to have medical than psychoactive effects.

It was also suggested that some cacti can reduce the risk of cancer, or have potential as antibiotics, antihypertensives or cancer treatments. While the forums formally distanced themselves from the misuse of prohibited plants and substances, online discussions regarding the psychoactive/analgesic effects of wild-sourced plants potentially blur the divide between entheogenic use and online communities specialising in certain species. This raises concern over the potential for both health-related and environmental harms, and represents an overlooked intersection of environmental crime, illegal online trades and drug use. (For further details, see [84]).

'bad', and that historical events should not be used to justify poaching today. In one example, a vendor who had supplied a wild-sourced plant to a forum member was vilified, with respondents imploring others not to collect specimens from the wild. Suspicions that a forum member had knowingly broken the law in order to bolster their collection, were raised, with this behaviour regarded indefensible. Plant shows were also criticised by some forum members for exhibiting suspicious-looking plants (although they did not provide examples to support this).

A subgroup of horticultural forum members agreed that they all should be working against the destruction of endangered and slow-growing cacti. They emphasised that wild sourcing is unnecessary and were aware of the stress this causes to populations threatened by other human activities. Some *Euphorbia* enthusiasts attempted to raise the issue of illegal poaching and illegal international trade, while another posted that they were very saddened by the apparent blindness of some forum members to the damage that poaching can cause. Two forum members expressed annoyance at the depiction of hobbyists within media articles discussing plant trafficking, which they felt portrayed them as 'grubby old men' with no concern for conservation or legality.

In this context, a third 'us versus them' narrative element is found. One forum user in particular felt that those with experience and sensitivity for conservation issues should educate those relatively new to the hobby (in this instance, reference was made to new collectors in China) who may not realise the implications of trading illegally sourced plants.

Community policing of online trade

The ability of these communities to initiate more active interventions was also in evidence. Several forum members described occasions where they had attempted to raise the alarm over suspicious trading they had encountered online. These attempts were directed at enforcement authorities and online platforms, and forum members expressed frustration at the lack of recognition or response. It was suggested a number of authorities had been contacted, or would be potentially suitable to approach, including CITES authorities, HMRC, the US National Park Service and UNESCO. Of the trading platforms, several forum members claimed to have contacted eBay. Generally, it was felt, this had been unsuccessful, although one forum member reported that they had stopped an auction by using eBay's online reporting form. Overall, these online community members felt disheartened by the lack of response and follow-up communication from those they had tried to contact, which left them feeling that the act of reporting had been pointless.

It was suggested that a form of 'online vigilantism' could be conducted by forum user groups, who by working together may be more successful in drawing attention to online activity of concern. On some occasions forum administrators intervened in online conversations. In the case of one horticultural forum, this was to clarify that under no circumstances did the forum wish to be associated with illegal trade. In another instance, the intervention was of a different capacity. Here, the moderator warned forum members to be careful of making accusations of illegal trade, which could damage the reputation of individuals and create a difficult legal situation. In these instances, the identity of the administrators and the basis of their authority within the forum was unclear.

Online trade in derivative products

Trade in *Saussurea costus* derivatives centred on online marketplaces, which are more impersonal than online forums. This provided an opportunity to test the FloraGuard methodology in these types of specialist retail settings.

Trading patterns and platforms

Saussurea costus products were found widely advertised on a number of online sales and auction sites. Of these, adverts from three major platforms – eBay, Alibaba and Etsy – were analysed in detail. Initial results generated by the keywords 'costus' or 'lappa' included adverts relating to species other than *Saussurea costus.* As these were not CITES-listed species they were beyond the focus of our investigation and were excluded from the analysis. It was, nonetheless, interesting to note the wide variety and availability of traditional medicinal products promising health-related benefits for afflictions ranging from lifestyle problems to very serious medical conditions.

Saussurea costus was generally sold online as powder, oil or pills. On eBay and Alibaba, raw herbs and whole roots were occasionally available. When sold as powder or oil, suggestions of how to prepare and administer it were provided. Product descriptions were consistent with the herb's popularity as a supplement in both TCM and Indian Ayurvedic medicinal practices. Products were often advertised as aiding the rejuvenation and health of the whole body, with particular benefits for the reproductive organs, abdomen, and diseases of the respiratory system.

Buyer and seller profiles

In all markets there was a mix of generalist sellers and vendors specialising in health-related supplements. Sellers were primarily based in India and China, which is to be expected given the scale of commercial cultivation that occurs in both of these countries. One major UK-based seller was active in all markets, while two vendors from Morocco and Australia were active on eBay. Other vendors were based in Pakistan and, in one case, Syria. Some UK-based companies appeared to be formally associated with Indian enterprises. In all three markets sellers with different names presented verbatim product descriptions, suggesting that some sellers may operate under multiple names.

Adverts on all three platforms targeted international markets. On eBay and Alibaba, some adverts were provided in English, French and Spanish. Worldwide shipping was usually available, with transit times ranging from 15 to 45 days depending on the destination. Shipping made use of national postal services, including those of India and China, and international courier companies.

Adverts on Etsy and eBay appeared to be primarily designed for individual consumers. Quantities of powder offered were frequently 100 g or less and products were commonly sold in a ready-to-use form such as pills and oil. Prices for powder ranged from £5 to £10 per 50 g. In some cases, sellers advertised larger quantities of 1 kg or more. Wholesale bulk sales, presumably targeted at resellers, was also available. The price for bulk sales was generally lower, with powder reaching a maximum of around £5 per 50 g.

It was generally not possible to establish where buyers may be located. *Saussurea costus* is known to be used by some herbalists outside of China, including within the EU although, here again, it was not possible to determine to what extent TCM practitioners may be purchasing these products. Some insights were gained from a small number of sales on Etsy, where it was possible to crawl some buyers' reviews. From these, it appears customers of a UK-based seller were in the Philippines and the United States.

Plant provenance

While artificial propagation is widespread in both India and China, confirmation that the plants originated from these sources was largely absent, with the exception of a few posts on Alibaba. Product images did not prove useful as many were in highly processed (e.g. powdered) forms, while others showed unprocessed roots, which alone cannot be used to differentiate between wild-sourced and cultivated plants.

The ingredients lists for derivative-based products also lacked transparency. For instance, within TCM the term Mu Xiang represents the 'official' drug derived from *Saussurea costus*. The same name can, however, also be used more broadly, and may represent a number of different ingredients unrelated to this species. Such overlaps in terminology can complicate enforcement efforts, and while a detailed analysis of ingredients lists was beyond the scope of this study, one eBay advert stated that the product's packaging may contain different information to that on the website. One possible explanation for this discrepancy is that incorrect labelling may have been used to avoid custom controls.

Evidence of IWT

The difficulties in ascertaining plant provenance and the lack of visible online discussion between vendors and consumers made it hard to determine the extent to which illegally wild-sourced products could potentially enter these supply chains. The use of CITES certificates (or comparable certification, as used, for example, by India) would offer some assurance, but details of the sustainable sourcing of *Saussurea costus* was absent from the online materials observed, and within more than 1,200 adverts sampled, CITES was never explicitly mentioned.

Around a third of posts, in all markets, specified that compliance with legal regulations was the buyer's responsibility. It is possible that the cost of CITES permits may make some international transactions for smaller volumes of product economically unrealistic, although the range of permit charges that are applicable in different regions of the world makes this difficult to ascertain. Overall, the general lack of transparency surrounding CITES processes made it impossible to quantify the proportion of international transactions that were likely to comply with CITES regulations.

Around a third of posts, in all markets, specified that compliance with legal regulations was the buyer's responsibility.

Saussurea costus roots

7. Key findings

The FloraGuard project aimed to explore alternative and interdisciplinary approaches to detecting and investigating internet-facilitated trade in endangered plant species. The case study investigations provided direct insights into this trade, and enabled the development of a methodology with potential applications for the investigation of different types of internet-facilitated wildlife trafficking, along with other types of illegal online markets.

7.1 Insights into the internet-facilitated trade in threatened plants

The results support those of previous research studies, in providing evidence that the internet helps facilitate trade in endangered plant species. The international nature of connectivity between potential vendors and consumers in both forums and marketplaces highlights the need for equally global efforts to ensure that such trade is conducted legally.

In some of the posts analysed there seemed to be direct evidence of plant poaching. Several wild-sourced (and likely illegal) specimens were openly discussed within forum threads. Discussions relating to the suspicious activities of individuals and organisations and practical tips relating to the evasion of enforcement agencies suggest the nature of illegal activity that may take place in offline settings.

Criminological analysis provided insights into attitudes behind the apparent disregard for CITES procedures exhibited by some forum members. These included a disrespect for authorities aiming to prevent wild plant collection and a lack of acceptance of the damage that illegal harvesting can cause. The use of neutralisation techniques to frame these arguments suggests a degree of denial and perhaps ignorance on the part of those collectors who are critical of the current regulations designed to protect wild plant populations.

The extent to which such attitudes may influence behaviour in offline settings is unclear. In internet-facilitated criminality, it is common to experience digital drifts[85], whereby deviance becomes more casual and transient in the anonymity of cyberspace[86]. Some individuals may not have a serious commitment towards criminality but nevertheless find themselves doing something beyond the limits of legality in a setting where criminality can be performed with a few mouse clicks. This category of offender may be better targeted by soft interventions, helping to prevent unnecessary criminalisation and the excessive deployment of policing resources.

While indications by some forum members of an apparent willingness to condone or participate in illegal trafficking may or may not match their actions in the real world, such comments deserve to be taken seriously. The widespread lack of consequences for online infringements may embolden those who are intent on committing environmental crime. The internet also provides a platform for them to influence others along with an easy entry point into illegality, which may see individuals moving easily between legal, semi-legal and illegal spheres[10].

The existence of forum subgroups based on 'us-vs-them' attitudes suggests that addressing IWT within these online communities may require a nuanced, multi-level approach. Interventions designed for experienced or expert forum members may be inappropriate for less experienced forum members, who may be more likely to purchase illegal plants inadvertently without realising the consequences. The resistance to CITES and enforcement agencies also suggests that finding ways to improve the perception of these organisations may be useful for engaging with online traders and consumers whose online behaviour suggests that they are at higher risk of buying or selling illegally sourced plants.

The existence of niche sub-cultures (in this case, entheogen forums) demonstrates that the online threats to plants may come from unexpected trends and developments in the offline world. The internet is particularly adept at connecting disperse people with shared interests, and forums provide a space in which social bonding and learning can take place[87]. Sudden interest in threatened species that occurs in unusual online settings is of concern, in the case of entheogens for both the health and environmental harms that may ensue. The internet at least provides a means of detecting and monitoring such developments – and gaining an understanding of the motivations behind each type of plant use is critical to the design of appropriate intervention strategies.

The positive attitudes towards plant conservation exhibited by many forum members also suggests opportunities may exist for engagement with individuals and subgroups. For instance, influential forum members may be able to promote and share accurate information relating to CITES procedures and the benefits of wild plant conservation. In some forums there also appeared to be an appetite among some forum members for some form of online community policing. This already takes place in an informal manner, with the active challenging of suspicious plant vendors occurring on more than one occasion.

More formally harnessing the 'eyes and ears' of these community members would require engagement and training in an appropriate setting (perhaps including,

for example, workshops facilitated in offline settings), and the means to report suspicious activity in a meaningful way – recognising forum members' frustrations that their efforts to report suspicious trade have rarely borne fruit. Less frequently, forum moderators' interventions were also evident. Greater understanding of the roles, responsibilities and capacities of forum moderators may suggest other opportunities for intervention strategies outside traditional enforcement channels.

Existing challenges relating to the detection of illegal trading online were also evident. Interpretation of online posts and images required careful evaluation, with definitive 'proof' of the illegality of potential transactions hard to ascertain. Complicating the picture, for trade in both live plants and derivative products, is the overwhelming lack of transparency that accompanies trade in CITES-listed species online. The lack of legal requirements for advertising content, the existence of dual domestic (CITES-exempt) markets, the potential for transactions to be concluded in private or offline, and the variable costs and procedures relating to CITES permits worldwide all make evaluation of suspicious online activity far more difficult than might be the case in a more highly regulated trading environment. While acknowledging these limitations to the data, it appears likely that a significant amount of online trade in CITES-listed plants may be conducted absent of CITES controls. Such opacity helps to mask the trade in plants illegally sourced from the wild, providing cover for those engaged in destructive practices that put the future of many species threatened in the wild at risk.

7.2 The advantages of an interdisciplinary approach

FloraGuard's interdisciplinary approach required input from subject matter experts in the fields of ICT, criminology, law enforcement, conservation science and horticulture. No one individual had all the knowledge required to collate, process and assess the data, but this combination of skillsets enabled the development of methodology that efficiently combined the strength of each discipline. The ICT-enabled approach proved that socio-technical workflows mixing information extraction tools with traditional criminological analysis can effectively reduce the volume of relevant posts that need to be manually analysed, speeding up the process. The use of NE directed graphs to examine and visualise the data also proved effective for exploring the connections between entities and presenting these in an interpretable way. The testing and selection of this tool in preference to LDA topic modelling is a reminder that despite the availability of individually powerful tools, there is currently no single off-the-shelf software solution for investigating internet-facilitated IWT. It is hoped that the results of this study may provide a useful foundation to build upon, leading to the development of new approaches tailored to the investigation of a wide variety of internet-facilitated IWT scenarios.

The resulting picture of online communications enabled the relevance of specific people, locations, species and organisations to be evaluated. This is similar in concept to the existing POLE data model of intelligence gathering employed by UK police forces, which builds linked categories of people, objects, locations and events within an investigation. NE directed graph visualisations did not, however, substitute for the experience of the criminologist. Keeping a human in the loop was deemed essential for making contextual judgements during investigations.

The information extraction technique proved adept at finding suspicious activity lurking in relatively small subsets of the data, such as posts buried deep within the 'long-tail' of forum threads. This enabled detection of activity that would likely have been missed by more traditional community-level analyses. The technique on its own was not perfect; its ability to detect entities of interest connected to a suspect ranged from 24% to 85% of what the criminologist uncovered using manual analysis. Here, the involvement of human judgement to evaluate and develop the machine-led analysis would mitigate for this shortcoming and enable information extraction algorithms to be integrated into qualitative frameworks, rather than viewing them as self-contained solutions.

To further enhance both the automation and accuracy of the technique, it may be possible to train other AI tools to recognise repeatable patterns observed within the data graphs extracted. This could potentially make use of a wide range of data attributes, ranging from discussions around payment mechanisms to the sharing of information regarding the avoidance of law enforcement controls, as have been noted in the current study. As the ability of AI to perform more automated tasks develops, so too will the debate around the use and application of these tools.

Two areas in particular that may prove integral to the future of online investigative work are summarised below and discussed in more detail in [90].

Ethical considerations

It is increasingly recognised that traditional ethical research practices do not always translate perfectly to online settings[88], and concepts such as anonymity, expectations of privacy and informed consent can present new challenges when applied to internet-based research. The interpretation of these concepts may depend on the context of the study or investigation, with needs to protect private or public information balanced against the wider benefits or cost to society of inaction. In practical terms, this includes consideration of the terms and conditions of source websites, the nature of user engagement with those sites (e.g. is it subscription based or free to access), the sensitivity of the information being posted by users, and whether the research could lead to increased risk for the researcher. While some institutions are gradually moving towards a common understanding of these implications, securing institutional approval of research requires engagement with the broad and constantly evolving debate

about the ethics of online research. This debate will be further shaped by potential changes to internet regulation that are currently being proposed in some countries.

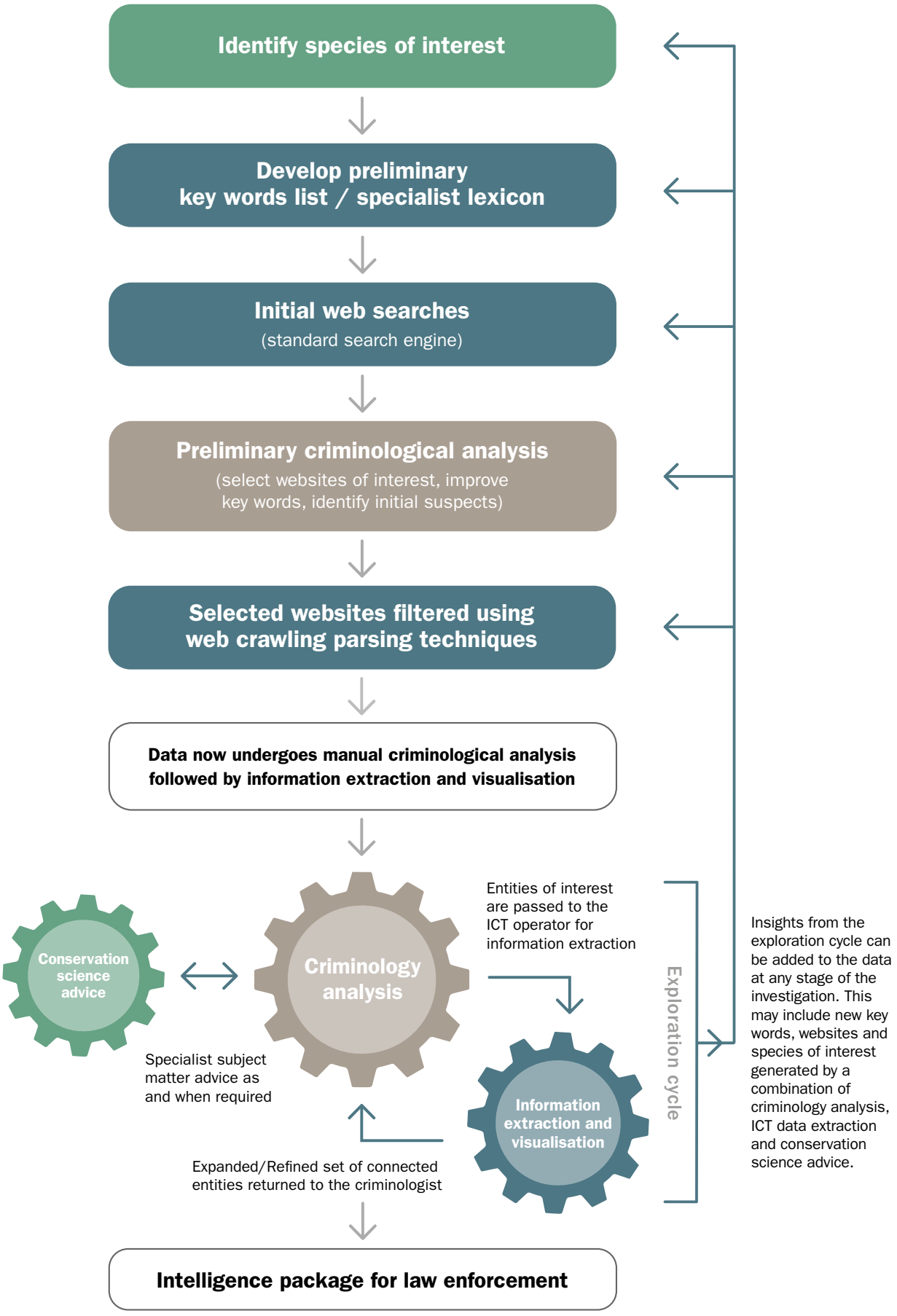
AI reviews

The datasets created by this methodology are iteratively populated throughout the course of the study, as the right keywords and search terms to return useful data from online forums were gradually discovered. As a consequence, the AI tools working with this data will inevitably contain some degree of data bias. To counter this effect, the methodology is designed to embrace and promote AI trustworthiness through the use of 'explainable AI' (i.e. computer's outputs that can be explained by a human rather than needing to be blindly accepted). There are two important ways of achieving this: firstly, the interplay between criminology, computer science and specialist human knowledge within the exploration cycle (see section 7.3) helps to prevent excessive generalisations being introduced by the automated processes and ensures that appropriate conclusions are drawn from the data; secondly, the use of provenance-preserving techniques enable data to be linked back to its original source, ensuring that any evidence gathered can be verified by independent human experts at any stage.

In addition to these safeguards, the authors propose that an 'AI review' step should be included in any real-world deployments of this type. This would be analogous to the ethics reviews conducted for research involving human subjects and personal data and would allow a panel of

FIGURE 3:

A proposed ICT-enabled methodology for investigating internet-facilitated IWT illustrating a typical workflow



experts to periodically review potential bias in sampling and training datasets that AI systems are using. The final decision makers who will receive the intelligence package must also be made aware of any limitations in coverage behind online crawled data, so that the appropriate mitigation strategies can be employed (such as sourcing corroborating human evidence where necessary). The conversion of human behaviour into data, known as 'datafication', is also known to be problematic in estimating crime patterns and guiding policy change[89]. By building trustworthiness into the AI approaches that adopt it, the proposed concept of AI review also aims to address concerns over the creation of policies that may increase in scope and importance as more aspects of human life move online.

7.3 A proposed ICT-enabled methodology for investigating internet-facilitated IWT

The performance of the ICT tools and qualitative insights from the study suggest that these can be effectively combined in an improved socio-technical approach to criminological data analysis. This would involve criminologists and computer scientists working together to explore the data in cycles, alternating between human-led analysis of the data, and the use of AI tools to follow up on leads in an iterative cycle of analysis. This ICT-enabled methodology is outlined in Figures 3 and 4. This sees the data analysis take place within an iterative 'exploration cycle', continuously adapted to respond to newfound data and inputs from a wide range of potential sources.

The initial stages of the investigation follow the methodology used within the FloraGuard case study investigations. Keyword lists are developed and used in conjunction with the web crawling and parsing software packages to extract posts of potential relevance from target websites.

This data is then subjected to manual criminological analysis and information extraction, based on natural language processing via NE directed graph visualisation software. This returns an expanded set of entities to the criminologist for further human-led analysis. To assist in this process, the data is visualised within NE directed graphs, which make it easier for discovered connections between the entities of interest to be viewed and evaluated. This cycling of data can be repeated as often as necessary to pursue leads during the course of an investigation.

Additionally, new information that is uncovered may also be fed back into any earlier stage of the crawling pipeline for incorporation within the next round of data analysis. This may include the expansion of the search to include new species or websites of interest that may have emerged during the initial phase of the investigation. Updates may also be made to the keywords list to incorporate new terms, locations, names, or other information of relevance that has become known (such as new vendors discussed in forum posts). These insights may be generated by any of the inputs to the data analysis process, including those of conservation scientists (for example, through the analysis of images to confirm the identity of species, or evaluate suspicions of wild sourcing). To implement these updates, continual adjustments and refinements to each of the ICT tools are required, including: changing keyword configurations for new websites; editing templates of HTML tags associated with forums so the parser can know what to scrape from HTML pages; and editing configuration files with filter settings for information extraction and NE graph visualisation code (and then running the code). This flexible approach enabled the search tools to be optimised throughout the course of the study in a way that would not have been possible using an unchangeable software package or product.

By continually reviewing the context of online posts and the connections between entities, the criminologist corroborates the machine-generated data, evaluating the context of the behaviours observed and the sentiments behind them and applying notes regarding their relative importance to the final dataset. This combination of ICT tools and human expertise enables analysis of far more online content than is possible by manual criminological analysis alone. Scope is limited only by the number of posts the criminologist can process at any one time and the total time available for the study.

Once a satisfactory analysis of the data has been concluded, the evidence generated could be passed to law enforcement agencies. It can be challenging for online intelligence to reach the evidential standard required to be presented in a court of law, but because links are maintained enabling entities to be traced back to the original online posts mentioning them, in principle it is possible that a target-focused evidence package could be generated. This might contain a record of all posts featuring a target suspect, along with details of the connected entities mentioned in these posts, contextualised with notes from the criminologist. Links to corroborating evidence from other intelligence sources could also be added. This type of provenance-based intelligence package might then meet the evidential standard required to support prosecutions. As an illustrative example, an indication of how a typical workflow might look is given below, although due to the iterative nature of the technique any number of variants is possible.

TABLE 7:

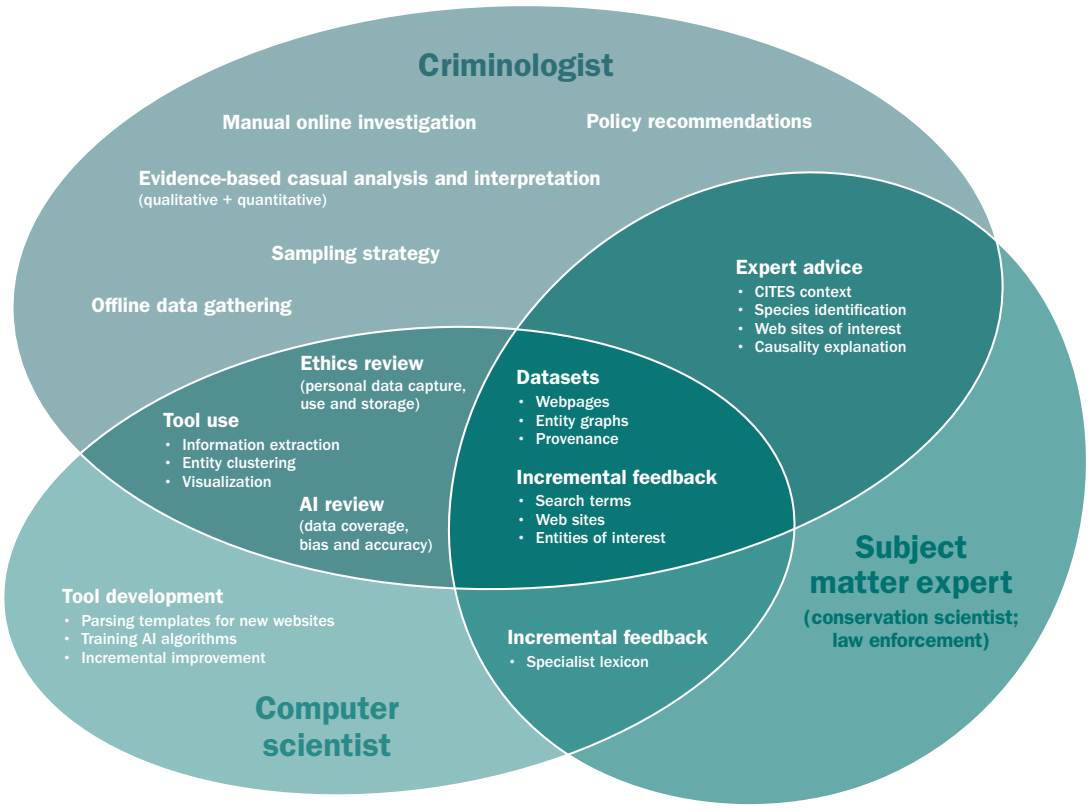
Example workflow of a typical ICT-enabled methodology investigation

Process	Typical actions involved
Bing search	Find sites using keywords
Manual criminological data analysis	Improve keywords, identify a few initial suspects
Web crawl and parse sites using keywords; perform information extraction and visualisation	Identify connected people/places/species/organisations
Manual criminological data analysis	Review new suspects, reject some, add others to list
Re-run information extraction and visualisation (using new suspect list) on current datasets	Identify connected people/places/species/organisations
Manual criminological data analysis	Review new suspects, discover a couple of new websites being referenced and add to the list
Web crawl and parse new sites; perform information extraction and visualisation	Add new datasets and identify connected people/places/species/organisations
.... loop many times until satisfied or out of time...	
Compile intelligence package	Present information on suspects, connected entities and behaviours (with links to online evidence)

Due to the highly iterative nature of the methodology, the precise workflow will be bespoke for each individual investigation. The methodology can therefore only be viewed in its entirety when considered as a fluid overlap of inputs from the different disciplines involved, any of which may influence the course and direction of an investigation (Fig. 4).

FIGURE 4:

FloraGuard ICT-enabled criminology analysis methodology, in its entirety. The overlaps between inputs represent the flexible and highly iterative approach, which can be adapted throughout the course of an investigation. Source:[90].



Mammillaria zeilmanniana

8. Recommendations – looking to the future

Herbal medicines on sale in South Korea

The FloraGuard study supports the findings of previous research demonstrating the ways in which internet-facilitated trade in endangered plants can undermine and circumvent the workings of CITES, and in doing so, threaten the survival of rare and endangered plant populations around the world.

In recent years, action to counter the use of the internet to facilitate the illegal trade in fauna has made encouraging progress. Yet, perhaps due to the effects of plant blindness (see Topic Box 8) combined with the size and complexity of the task involved, similar protections for plants appears to be lagging behind. An opportunity now exists to bring the internet-facilitated trade in plants into focus, with the following ideas and recommendations intended to stimulate discussion regarding potential interventions and next steps.

8.1 Development of investigative tools

The proposed ICT-enabled methodology represents a new technique ready to be trialled in the field. This could be employed by a range of stakeholders for research and investigations where forums and online marketplaces are suspected to be involved. The principles of the technique could also be applied to other types of websites, including social media and other deep web sites, provided access to these typically more closed internet settings was granted. Recording information about frequent traders and identifying hotspots of illegal trade would help to direct resources appropriately and would form an important step towards making enforcement interventions in the real world.

Monitoring forums around the times of major plant shows, or following the discovery of a new species, would be further ways of performing targeted investigations to track the activity of suspect individuals.

The technique has not yet been tried in a real enforcement operation; testing the data to an evidential standard within a legal setting is necessary, if its potential support for traditional law enforcement is to be realised. To provide capacity for such work, the training of specialist teams in criminology, ICT techniques and conservation science in relation to the online trade in plants would be required. Computer science operators must be proficient in the use and adaptation of the crawling, parsing and information extraction tools, which are run and re-run via a command-line prompt. With further development, the operation of these tools could be simplified, although the technique is most powerful when the tools are adapted during the course of the investigation, enabling the team to quickly respond to new information. While each area of expertise requires a base level of specialist knowledge, the authors believe the technique would be transferable to appropriately skilled teams, who could begin to use it after a moderate amount of training.

Rimacactus laui

This proposed methodology is, however, far from an end point. Rapid advancements in computer science mean that it also represents a building block for future development and adaptation, not least to keep pace with the ever-changing nature of internet-facilitated IWT. Developments in countermeasures to combat other forms of cybercrime may also prove useful in helping to identify and disrupt illegal wildlife traffickers online.

A methodical evaluation of online trade in threatened species also has the potential to support other policy measures, such as changes to species' conservation status. For example, manual online searches to assess the nature and potential impact of online trade are often performed to support proposed changes to CITES listings. A more standardised and in-depth approach to searching relevant online content might help to confirm or remove suspicions, cast a new light on anecdotal evidence, or horizon scan for species which may be involved in emerging patterns of trade.

8.2 Development of platform policies and other legislation

Many technology and e-commerce companies have already demonstrated a strong commitment to the development of new policies designed to deter online trade in threatened animal species across their platforms. A review of platform policies to ensure they offer sufficient clarity and support for the sustainable trade in CITES-listed plants may be a logical next step. This might be achieved through updates to the terms and conditions in consultation with conservation experts. Given the complexities of the trade in plants, other measures might also be considered. For example, it's arguably simpler to ban trade in certain readily recognisable Appendix I animal products than it is to prevent trade in illegally wild-sourced plants while facilitating trade in their artificially propagated counterparts.

Additional measures might include the introduction of trading mechanisms such as declaration forms to encourage compliance, which have previously been suggested by researchers working in this field[36]. Systems of registration and/or the use of online declaration forms detailing plant provenance, CITES permit requirements, costs and timeframes may help to promote transparency around the trade in CITES-listed species. An absence of such details would then immediately raise suspicions, while fraudulent declarations could be more easily unpicked and exposed. The impacts of such policies on trade may need evaluation, although as CITES permits are already expected to be a legal requirement for international trade, the additional administrative burden imposed on businesses would appear minimal. The development of such policies would require input from all relevant stakeholders including law enforcement agencies and, depending on the outcome of such discussions, could potentially be trialled on a voluntary basis, reflected in platform policies or even enshrined within national legislation.

Engagement with postal and courier shipping companies may prove a useful compliment to other forms of intervention. This has proved fruitful in efforts to combat the online trade in endangered animals[20], and the potential role of shipping companies to deter or detect the shipment of illegally sourced plants could be further explored through consultation with these companies.

8.3 Awareness raising and behaviour change strategies ('soft' approaches)

Given the scale of the challenges involved, law enforcement interventions may only be appropriate, and indeed possible, in the most severe cases of plant trafficking. Aside from the impact upon police resources, the social impacts of excessive criminalisation are also undesirable – while for the preservation of endangered species, prevention of poaching is far preferable to later recrimination.

Reducing demand for wildlife products by encouraging behavioural change is an important component of many conservation interventions. This may include raising awareness of conservation issues within online communities by providing targeted messages – an approach that has proved effective in tackling the online trade in drugs[91]. The use of forums by hobbyists to engage in open discussion suggest that the use of 'soft' interventions to counter potential illegality may prove effective. Encouraging influential and experienced forum members to share information and provide advice may be a useful and relatively cost-effective prevention strategy. In an ad hoc way, this is already happening within some forums, and the systematic use of accurate and up-to-date messaging may help to promote sustainable trading and dissuade the activities of illegal traders operating within these online spaces. Such messaging could ensure that the rationale for CITES permits is understood by potential consumers, and links to the information that is required to apply for CITES permits could be provided. Key questions to ask vendors could be standardised, to help consumers conduct checks prior to purchase.

Forum moderators and administrators could potentially become involved in awareness raising and information sharing within their forums, once their current roles, capacities and potential willingness to participate are better understood. The enthusiasm among some forum members to engage in community policing could also be better harnessed by providing a clear means of registering their concerns over suspicious online trading with relevant authorities.

Popular media's awareness of plant trafficking crimes is already increasing, and linking such awareness with real-life examples may help to strengthen the messages received by the public.

8.4 Summary of recommendations

The key recommendations generated by the study are summarised to the right. Key requirements and potential implementation challenges for each recommendation are also briefly discussed.

Recommendation	Requirements and implementation challenges
Development and application of ICT-enabled investigative methodologies	
Use of ICT-enabled criminological analysis within real-world, intelligence-led investigations.	Evidence from online investigations could be used in conjunction with other investigative techniques. Use of this evidence to help secure convictions would require testing in a legal setting. The development of specialist teams may also allow more routine monitoring of internet trade. One-off investigations or long-term surveillance would require funding and the means of following up on results. Measures of success with funding donors would need to be agreed.
Additional training for law enforcement regarding indicators of illegal trade online, including in recognising species-specific differences between wild-sourced and nursery-grown plants.	Advice from enforcement authorities regarding the species for which this would be most useful, and the best ways of sharing this information internationally. In addition, existing training models should be backed up by a mentoring model considering the specificities of IWT (see also [74]).
Training law enforcement on the future use of AI tools in socio-technical deployment, such as the setting up of formal AI reviews. This would help decision makers use AI results in well informed ways, understanding both the capabilities of AI and its capacity for error/bias (e.g. understanding if there is training set bias in AI tools being deployed).	Funding and buy-in from enforcement authorities, and collaborations with independent academic researchers to advise on AI reviews.
Preparedness to adapt to developments in technology.	Current methods of investigating internet-facilitated IWT, including the methodology proposed by this study, must continue to draw on developments in this field and in cybercrime more generally. Cross-pollination of techniques is likely to accelerate the development of solutions to further automate surveillance of online marketplaces, helping to maximise the impact of limited conservation and enforcement resources.
Preparedness to adapt to changes in internet-facilitated IWT.	Additional scrutiny of internet-facilitated trade in plants could see illegal traders adapt their tactics online. This might include the use of code words, or the relocation of illegal trade to more secretive areas of the internet. The need for any such adaptation might be viewed as initial success, but only if subsequent shifts in trade are met with similarly robust responses.
Development of online platform policies	
Raise awareness with e-commerce companies, including of the issue of plant blindness. This could be followed by engagement to help develop policies and practices to adequately deter and disrupt the illegal trade in endangered plants across their platforms.	Commitments from technology and e-commerce companies to tackle illegal trade in endangered plants across their platforms with the same vigour as illegal trade in fauna. Opportunities must be sought to raise awareness with the public, while improving brand image. Innovative interventions to help regulate online trade could be developed in conjunction with major trading platforms to create a gold standard approach.
Raise awareness with postal and courier companies, followed by engagement to determine whether intervention points may exist within the transit chain, for example through the detection of plants shipped under misleading goods declaration forms.	Commitments from postal and courier companies to review systems and explore potential solutions.
Engagement with plant trading communities	
Raise awareness among plant traders and buyers within online communities. This should include efforts to dissolve any existing barriers between some members of these communities and the institutions that enact CITES legislation.	Commitments from horticultural societies and industry bodies to support and help facilitate awareness-raising initiatives. This could involve increased use of moderators to engage with forum members on issues of conservation science and the legal status of species. Outreach might take the form of workshops, webinars or the publication of articles about biodiversity protection and the positive role that horticulturists and users of plant products can play.

Recommendation	Requirements and implementation challenges
Engagement with plant trading communities	
Target specialist collectors with online behaviour change initiatives.	Development of bespoke messaging and delivery systems. These would be aided by support and insights from horticultural societies and industry bodies.
Encourage community policing within online forums.	Develop a mechanism through which suspicions can be flagged with the appropriate authorities, ensuring that all enquires are acknowledged and receive a response.
Legislative considerations	
Renewed consideration among national CITES authorities of the need for more stringent requirements for the online trading in CITES-listed species of plants.	Policies designed to better regulate online trade would need to be matched by police resourcing to enforce them.
A review of the penalties imposed for different forms of internet-facilitated illegal wildlife trade, to ensure that crimes involving the destruction of wild plant populations are treated appropriately.	More frequent prosecutions and heavier sentences place a burden on police time and resources. Raising the level of risk perceived by wildlife traffickers may help to deter low-level offenders from 'drifting' into illegality, while more serious sanctions for persistent offenders may hamper their future ability to poach, and signal a zero tolerance approach to the illegal removal of endangered plants from the wild.

8.5 Final thoughts

The successful conservation of threatened plants ultimately requires preventing their illegal harvest at source. The results of this study support ideas for a range of interventions that would help this aim by disrupting illegal use of global online markets and stemming demand for these species.

It is hoped that by generating evidence around the performance of ICT-enabled criminology methodologies, a case can start to be built for wider adoption of these socio-technical approaches within the work of law enforcement and other relevant stakeholders involved in the identification and prosecution of wildlife crimes. Of equal value is the deeper understanding brought by this interdisciplinary approach of the socio-economic and socio-behavioural aspects of these crimes. These insights have the potential to inform a range of alternative interventions, 'softer' than traditional enforcement but, for the conservation of endangered species, potentially more effective.

By connecting disciplines in this way, solutions to tackle IWT in its digital form are easier to develop and more powerful in their execution. However, such investigative techniques should be viewed as treatment rather than cure. Many of the challenges presented in this study stem from the commercialisation of cyberspace, which is developing faster than the capacity to regulate and monitor all its aspects. The trade in plants is particularly left behind in this respect. It is hoped that the FloraGuard study may provide useful impetus in redressing this balance, as well as adding to the armoury of enforcement agencies charged with combating IWT in all its forms.

As the global community prepares to take a new stance on biodiversity protection, this persistent problem is likely to be at the forefront of calls for fresh ideas and robust solutions. The internet's role in facilitating the illegal trade of endangered plants must not be overlooked in the design of these future goals. As evidence surrounding this neglected threat to biodiversity mounts and tools to counter it are refined, new collaborations and commitments to tackle it are timely and valuable steps forward. Rather than allowing cyberspace to undermine the protection of endangered flora, the vast reach of the internet might instead be harnessed to promote the conservation of some of the world's rarest and most iconic plants, and to deploy innovative solutions to help guard against their loss.

Saguaro in the Sonoran Desert in Arizona

9. Glossary of terms

Term	Definition
Algorithm-based processes	An algorithm is a finite sequence of rules which enable calculations, computations or other problems to be solved. In computer science, algorithms enable the optimisation of a wide range of processes. They must be used with care to avoid introducing biases or other unwanted effects into the systems they help control.
Artificial intelligence (AI)	AI describes the ability of machines (and software) to perceive their environment and take actions to maximise their chances of successfully achieving specific goals.
Command-line prompt	A command-line prompt is a command-line interpreter application available in most Windows operating systems. It is used to execute commands, including the running of specialist and bespoke software packages.
HTML	Hypertext Markup Language is the form in which standard webpage content is stored and transmitted over the internet. Web browsers receive HTML documents from a web server and render the documents into multimedia web pages.
Information and Communications Technology (ICT)	ICT extends the concept of information technology (IT) to place an emphasis on the integration of communications and telecommunication devices. It covers any device that will store, retrieve, manipulate, transmit or receive information in a digital form.
Information extraction (IE)	Information extraction refers to the automatic extraction of structured information from unstructured or semi-structured machine-readable documents or other electronic sources.
JSON files	JavaScript Object Notation (pronounced 'Jason'), is an open standard file format that uses human readable text to store and transmit data.
Latent Dirichlet Allocation (LDA)	A generative statistical model that allows sets of observations to be explained by unobserved groups that explain why some parts of the data are similar.
Machine learning	Machine learning is a subset of AI. It refers to algorithms that improve automatically through experience. Machine learning algorithms work by building mathematical models based on sample data (known as training data), in order to make predictions or decisions without being explicitly programmed to do so.
Metadata	Metadata is data that provides information about other data. There are many different categories, with descriptive metadata containing information about a resource that enables it to be identified (e.g. title, author and keywords).
Natural language processing (NLP)	A subfield of linguistics and AI concerned with the interactions between computers and human (natural) languages, in particular how to program computers to process and analyse large amounts of natural language data. Information extraction is a subfield of NLP.
Parsing	Parsing (from the Latin pars, meaning part of speech) refers to the analysis of symbols such as natural language, computer languages or other data that conform to the rules of a formal grammar. It can be applied to many situations, including the extraction of meaningful text from HTML data sets.

Term	Definition
Pagination	Pagination is the process of dividing a document into discrete pages (electronic or printed).
Paging feature	A starting point/entry point for web crawling software to access the contents of a website.
Pseudonymised data	Pseudonymisation is a data management and de-identification procedure which replaces personally identifiable information with artificial identifiers (pseudonyms). This makes the data less identifiable, while remaining suitable for fine-grained data analysis techniques.
Uniform resource identifier (URI)	A URI is a string of characters that enables the identification of a specific resource. This identification enables interactions with the resource over a network such as the internet. The most common form of URI is the uniform resource locator (URL), otherwise known as a web address.
Web crawler / Web crawling	A web crawler (often shortened to crawler) is a software application (known as an internet robot, or bot), which systematically browses the internet for websites relevant to its programmed search criteria.
Web scraping	Web scraping software searches for specific information on specific websites or pages. While web crawling creates a copy of the information, web scraping extracts specific data for analysis.

10. Acronyms

CITES	Convention on the International Trade in Endangered Species of Wild Flora and Fauna
HMRC	Her Majesty's Revenue and Customs (UK)
INTERPOL	International Criminal Police Organization
IUCN	International Union for Conservation of Nature
TCM	Traditional Chinese Medicine
UNESCO	United Nations Educational Scientific and Cultural Organisation

Conophytum concavum

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Appendix A. Species profiles

The following section outlines the key characteristics of the plant groups selected for the FloraGuard study. This includes an overview of records contained within the CITES trade database, which provide insights into the scale and nature of international trade involving these species. Such research forms useful preparation for investigations into online trade in threatened plants, by enabling the risk posed by trade involving certain combinations of species, products and countries to be evaluated in advance.

PLANT GROUP 1:

Family: Cactaceae
Genus: *Ariocarpus*

Ariocarpus is a cacti genus native to the north Mexican Highlands and, in the case of *A. fissuratus*, the southern United States. The genus includes seven species (Table 8), characterised by stout roots supporting densely packed tubercles (usually absent of spines except in seedlings)[1]. They take several years to reach flowering size and this slow growth, coupled with their appearance, has led to them being known as 'living rocks'. Their ability to produce large, attractive flowers adds to an appeal which has lasted for centuries. In 1830, Baron Wilhelm von Karwinsky is said to have sold a specimen he had collected from Mexico for 1,000 francs – at the time, a sum exceeding that of the plant's weight in gold[2]. Such fascination with these cacti has unfortunately been to the detriment of many wild populations. Over-collection for horticulture and for use as medicinal derivatives compounds the habitat loss that also threatens these species. Recent examples of suspected poaching and illegal trade include a seizure of 200 *Ariocarpus fissuratus* specimens by US Customs and Border Protection in December 2018[3]. Customs seizures are also regularly recorded in the CITES trade database.

Its slow growth makes it difficult to replenish wild *Ariocarpus* populations that have been impacted by illegal collection. As they are poor self-pollinators, the loss of mature individuals may hamper the reproductive capacity of an entire sub-population[4].

Artificial propagation is possible, although specimens may take as long as 15 years[3] to reach commercially viable market size. Transparency regarding the origin of mature specimens in trade is therefore of particular importance for this genus. In addition to the trade in live plants, *Ariocarpus* seeds are also frequently sold online, with these seeds (and therefore also the provenance of their parent plants), subject to the same CITES controls.

Ariocarpus fissuratus

TABLE 8:

Conservation status of selected *Ariocarpus* species

Selected species	Common name*	CITES Appendix	EU Annex	IUCN Red List status (assessment year)	Distribution	Threats and vulnerabilities (source: www.iucnredlist.org)
Ariocarpus agavoides	Tamaulipas living rock cactus	I	A	EN (2009)	Mexico	Known from only six locations, within a total area of around 2,000 km^2. Illegal collection drives population decline and is considered a principle threat.
Ariocarpus bravoanus	None listed	I	A	EN (2009)	Mexico	*A. bravoanus* occurs at the fringes of the Chihuahuan Desert. Two subspecies are recognised. *A. bravoanus* subsp. *bravoanus* is known from a small area in Mexico. In the late 1990s, over 705 of the plants were removed from the location where it was first discovered. While some undisturbed colonies have been found, its entire range encompasses 4 km^2, and it is assessed as Critically Endangered. *A. bravoanus* subsp. *hintonii* is known from a greater number of sites, spread over 200 km^2. It is assessed as Endangered. At the species level, *A. bravoanus* remains in decline, due to the impacts of illegal collection, agricultural activities and other human disturbance. Locally, *A. bravoanus,* along with several other *Ariocarpus* species, is used medicinally.
Ariocarpus fissuratus	Chautle living rock	I	A	LC (2009)	Mexico/US (Texas)	*A. fissuratus* is a relatively wide-ranging species. When assessed in 2009, illegal collection from the wild was thought to be occurring, although at a diminishing rate.
Ariocarpus kotschoubeyanus	None listed	I	A	NT (2009)	Mexico	*A. kotschoubeyanus* has been recorded at 35 locations around the edges of the Chihuahuan Desert. The estimated population of 100,000 mature individuals is very fragmented. Threats include habitat loss, waste dumps, illegal collecting and collection for local medicinal uses.
Ariocarpus retusus	False peyote	I	A	LC (2009)	Mexico	*A. retusus* has a larger range than some other *Ariocarpus* species, although much of this has been modified by agricultural development. Also threatened by illegal collecting.
Ariocarpus scaphirostris	Nuevo Leon living rock cactus	I	A	EN (2009)	Mexico	*A. scaphirostris* is known from just three locations which total 12 km^2. Its population is in decline due to illegal collection and habitat loss due to quarrying.
Ariocarpus trigonus	None listed	I	A	LC (2009)	Mexico	*A. trigonus* is found in semi-desert shrubland. A more extensive range and population size offers some security, although it remains threatened by illegal collecting and land conversion.

*An assessment of common names was made in English language only, using the IUCN Red List (www.IUCNredlist.org) and Species+ (https://speciesplus.net/) as sources. Other local and vernacular names are likely to exist for each species.

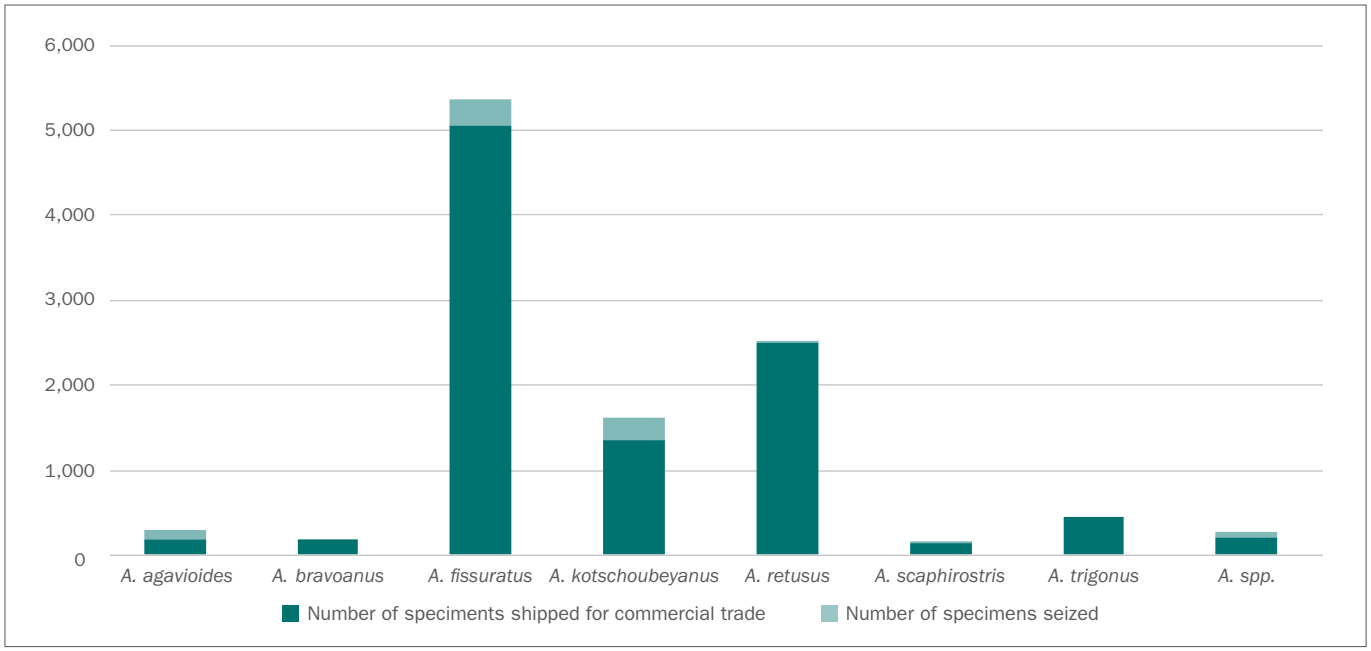
CITES trade overview

The following section provides an overview of the trade in live specimens of *Ariocarpus* species recorded by the CITES trade database, from 2008 to 2018 (the latest year with complete records available).

As Figure 5 shows, between 2008 and 2018 international trade in live specimens of *Ariocarpus* was dominated by *A. fissuratus*, *A. retusus* and *A. kotschoubeyanus*. The other four species, particularly *A. scaphirostris*, appeared far less regularly within international trade. Aside from a single entry for a wild-sourced *A. fissuratus* specimen (shipped from Germany to China in 2011), all permitted commercial trade was in artificially propagated specimens. During this 10-year period, the database also recorded 25 seizures of *Ariocarpus* specimens, ranging from a few specimens to several hundred plants, including a seizure in 2016 of 279 *A. kotschoubeyanus* specimens en route from Mexico to the United States.

FIGURE 5:

CITES recorded commercial trade in live specimens of selected *Ariocarpus* species, 2008–2018. Blue represents specimens traded in accordance with CITES regulations, orange represents specimens seized for being in contravention of CITES. *A.* spp. represents specimens traded without the identity of the species involved being recorded.



Euphorbia cylindrifolia

PLANT GROUP 2:

Family: Euphorbiaceae
Genus: *Euphorbia*

The genus Euphorbia comprises a diverse range of almost 2,000 species, which are distributed worldwide. The majority are annual or perennial herbs (spurges) which occupy temperate and tropical zones. Other species grow as trees or shrubs across the tropics and subtropics, while succulent *Euphorbia* occur in drier regions of Africa, tropical Asia, the Americas and Madagascar. Some of these succulents closely resemble cacti, although the arrangement of their spines in pairs enables them to be distinguished. A milky latex, which can be toxic or irritant on contact, is a further hallmark of the *Euphorbia* genus[5].

Succulent *Euphorbia* are regulated by CITES, with a few exemptions for species in well-established cultivation. Mexico's *Euphorbia antisyphilitica* is the source of candelilla wax, which has a wide range of commercial and industrial uses. Many species are popular within the specialist horticultural trade, with South Africa and Madagascar among the major suppliers of live plants. While this trade is supported by artificial propagation, many wild populations remain at risk of illegal collection.

The FloraGuard team decided to focus their search on ten succulent species of *Euphorbia* listed in CITES Appendix I. These species are native to Madagascar, an island nation whose unique natural resources are heavily pressurised. The wild collection of Madagascan *Euphorbia* species is known to have increased between 2011 and 2015, raising concerns that their international trade may be reaching unsustainable levels[5]. Additionally, three species endemic to the Canary Islands and Azores were also selected. These species' natural range is limited to their island habitats, and while they are listed in CITES Appendix II, they have been afforded the highest category of protection by the EU (Annex A). With trade in Europe under tighter controls, any suspicious or unregulated online trade may be easier to detect, with any suspicions of wild sourcing of particular concern for these range-restricted species.

TABLE 9:

Conservation status of selected *Euphorbia* species

Selected species	Common name*	CITES Appendix	EU Annex	IUCN Red List status	Distribution	Threats and vulnerabilities (source: www.iucnredlist.org)
Euphorbia ambovombensis	None listed	I	A	VU (2004)	Madagascar	*E. ambovombensis* is threatened by habitat degradation, land clearance for charcoal production and collection for horticultural trade.
Euphorbia cap-saintemariensis	None listed	I	A	CR (2004)	Madagascar	*E. cap-saintemariensis* is threatened by habitat degradation, wildfires, natural disaster and collection for horticultural trade.
Euphorbia cremersii	None listed	I	A	VU (2004)	Madagascar	*E. cremersii* is known from only four locations. Threatened by habitat loss, fire and collection for horticultural trade.
Euphorbia cylindrifolia	None listed	I	A	EN (2004)	Madagascar	*E. cylindrifolia* is known from around five locations. At risk from land clearance for charcoal production and collection for horticultural trade.
Euphorbia decaryi	None listed	I	A	EN (2004)	Madagascar	*E. decaryi* populations are severely fragmented, and are threatened by habitat degradation, land clearance for charcoal production, fire and collection for the horticultural trade.
Euphorbia francoisii	None listed	I	A	CR (2004)	Madagascar	*E. francoisii* is recorded from five localities and is threatened by habitat clearance for charcoal production, fire and collection for horticultural trade where it is highly prized.
Euphorbia moratii	None listed	I	A	VU (2004)	Madagascar	*E. moratii* is only known from two localities. Threatened by habitat degradation, fire and collection for horticultural trade.
Euphorbia parvicyathophora	None listed	I	A	CR (2004)	Madagascar	*E. parvicyathophora* is known from a single region, surrounded by heavily degraded habitats. It is sought after by succulent plant collectors, and also threatened by fire along with other forms of habitat degradation and loss.
Euphorbia quartziticola	None listed	I	A	EN (2004)	Madagascar	*E. quartziticola* has a very small extent of occurrence (222 km^2) and a small area of occupancy (62 km^2). Recorded from seven localities where populations are in decline due to habitat degradation, fire and collection for horticultural trade.
Euphorbia tulearensis	None listed	I	A	CR (2004)	Madagascar	*E. tulearensis* is locally common, but known from a single region. Populations in decline due to habitat loss and degradation, land clearance for charcoal production and collection for horticultural trade.

Selected species	Common name*	CITES Appendix	EU Annex	IUCN Red List status	Distribution	Threats and vulnerabilities (source: www.iucnredlist.org)
Euphorbia handiensis	Cardón de jandia	II	A	VU (2011)	Spain (Canary Islands)	*E. handiensis* has an area of occupancy of just 12 km² and is known from only two locations. While no specific threats have been identified, grazing pressure and wild collection are thought to prevent the species expanding its range.
Euphorbia lambii (E. bourgeana)	Tabaiba amarilla de Tenerife/ Gomeran spurge	II	A	VU (2011)	Spain (Canary Islands)	*E. lambii occurs* in the Canary Islands and is considered rare in its habitat. Threats to this species include habitat loss and degradation and collection for trade.
Euphorbia stygiana	None listed	II	A	Not assessed	Portugal (Azores)	*E. stygiana* has not been assessed by the IUCN. Its island distribution would make this species vulnerable to habitat loss and unsustainable use.

*An assessment of common names was made in English language only, using the IUCN Red List (www.IUCNredlist/org) and Species+ (https://speciesplus.net/) as sources. Other local and vernacular names are likely to exist for each species.

Euphorbia cap-saintemariensis

CITES trade overview

The following section provides an overview of the trade in live specimens of *Euphorbia* species recorded by the CITES trade database, from 2008 to 2018 (the latest year with complete records available).

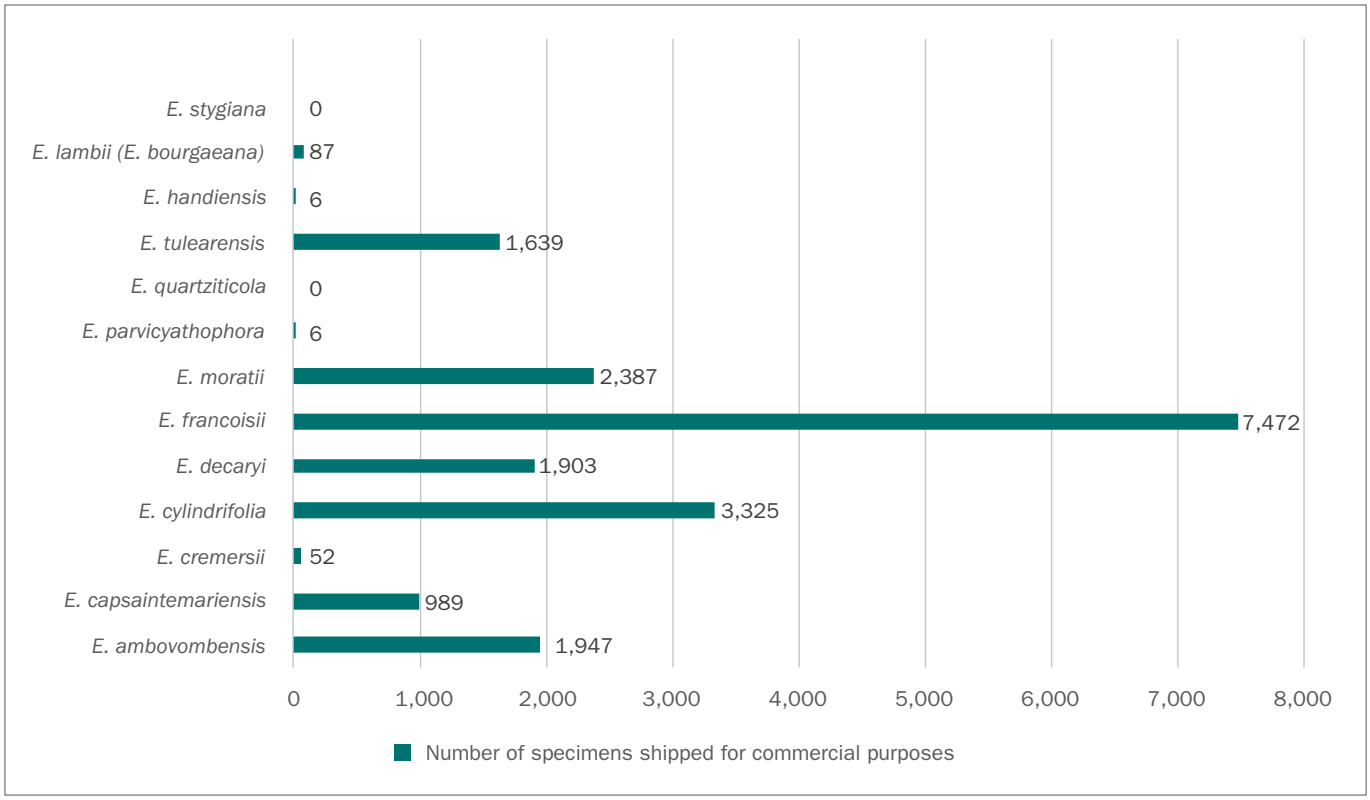
As Figure 6 shows, between 2008 and 2018 trade in live specimens of the selected Madagascan species was dominated by *E. francoisii*, followed by *E. cylindrifolia* and *E. moratii*. Conversely, *E. cremersii* and *E. parvicyathophora* were rarely seen in trade, and no live specimens of *E. quartziticola* were traded internationally during this time. Of the Spanish and Portuguese species, trade in *E. lambii* and *E. handiensis* occurs infrequently, while no records of international trade in *E. stygiana* were recorded.

This legal trade was almost entirely in artificially propagated specimens, with Thailand, South Africa, the United States, Germany and the Netherlands the most significant of ten commercial exporters, shipping to 48 different countries worldwide. The only exception was a shipment in 2013 of 16 wild-sourced *E. cylindrifolia* specimens from Germany to South Korea. The origin of these plants was not recorded. All shipments were approved by CITES authorities, and none resulted in seizures.

A smaller amount of trade in seeds, dried plants and roots is also recorded within the CITES database. This particularly involved shipments of *E. francoisii* and *E. tulearensis* seeds from Thailand, from artificially propagated sources, which occurred with some regularity between 2015 and 2018.

FIGURE 6:

CITES recorded commercial trade in live specimens of selected *Euphorbia* species 2008–2018. All trade was conducted in accordance with CITES regulations, with no seizures reported.



Saussurea costus

PLANT GROUP 3:

Family: Compositae
Genus: *Saussurea*
Species: *Saussurea costus**

***This name, used for CITES trade purposes, is a synonym of the accepted Latin name *Aucklandia costus*[6].**

Saussurea costus is a perennial herb native to the Himalayan region of India and Pakistan, where it grows at altitudes of between 2,600 and 4,000 m. This thistle-like plant grows to 2 m in height, although it is the stout roots that are highly valued for their medicinal properties. Often traded whole or in powdered form, these sweet smelling, bitter tasting roots are used to treat a wide variety of ailments, including chronic gastritis, rheumatoid arthritis, asthma, bronchitis, complaints of the gall bladder and other organs, indigestion and diarrhoea. Oils and extracts may also be used within antiseptics, insecticides, incense, hair oils and perfumes. The species is one of the most important medicinal plants of India, with the root traded in local, regional, national and international markets.

This wide range of valuable applications has led to over-exploitation. During harvest the whole plant is uprooted and this, combined with habitat loss and grazing pressure, has resulted in *S. costus* being assessed as Critically Endangered. In response, cultivation has reached industrial levels in India, with the country's last official wild harvests occurring in 2005. Since the 1960s, China has also widely cultivated *S. costus*, initially to supply its domestic TCM market, although production soon expanded to make China a major international exporter. By 2011, the bulk of India's own industrial demand (which totalled 150–200 MT per year), was thought to be supplied by China[7].

Due to these well-established sources of cultivation, it is unclear to what extent wild populations may now be impacted by illegal collection, for the purpose of supplying the international market. Yet the international trade in this species remains something of a puzzle. *S. costus* often ranks highly among the plant species seized by border agencies around the world, topping this list in 2011–2014, and coming second in 2016–2017[8]. The reasons for these regular breaches of CITES regulations are unclear. In some markets, a preference for wild-sourced products may exist, although it is likely that factors other than wild sourcing (such as administrative or permitting errors) also result in infringements.

TABLE 10:

Summary of the conservation status of *Saussurea costus*

Selected species	Common name*	CITES Appendix	EU Annex	IUCN Red List status	Distribution	Threats and vulnerabilities (source: www.iucnredlist.org unless stated)
Saussurea costus	Kuth, aucklandia, saussurea root, costus root	I	A	CR (2014)	India/ Pakistan	*Saussurea costus* is threatened by unregulated collection, illegal trade, loss of habitat and uncontrolled grazing. Indiscriminate collection from the wild has a severe impact on natural regeneration.

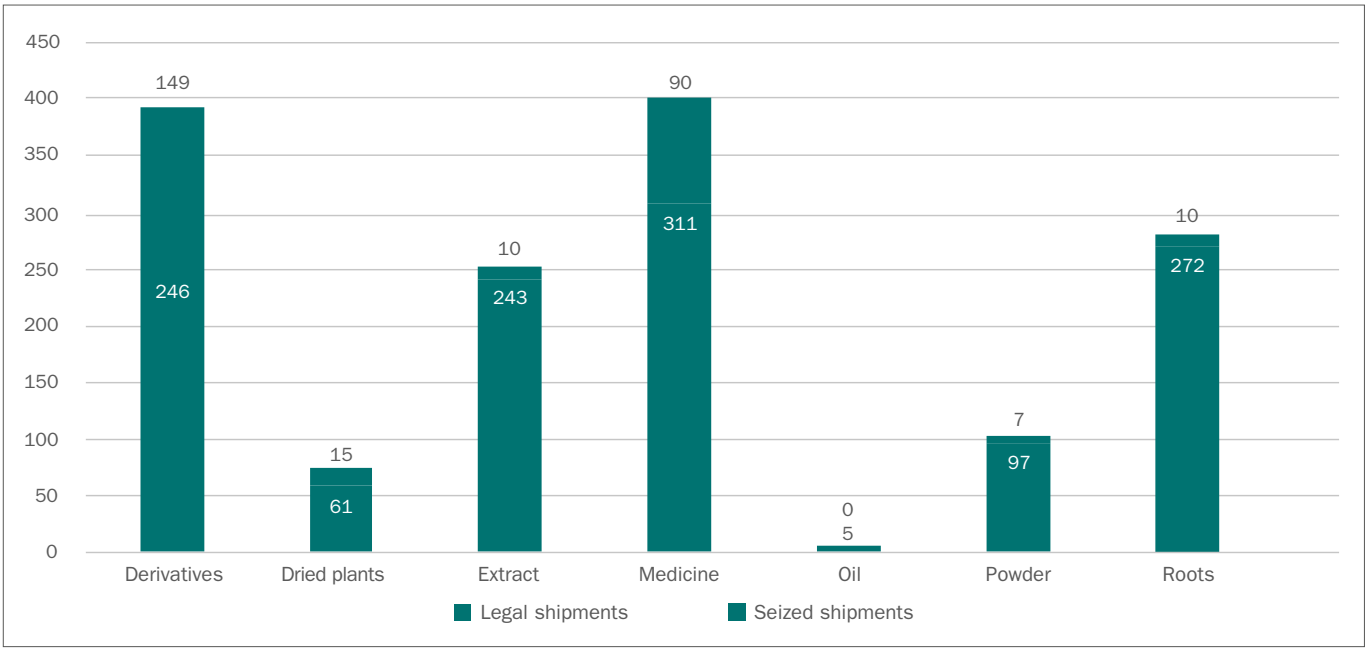
CITES trade overview

Saussurea costus is most frequently traded in the form of medicines, roots, derivatives and extracts. Between 2008 and 2018, more than 1,200 such shipments were recorded in the CITES trade database, ranging from products weighing a few grams to shipments of many tonnes (Fig. 7).

Figure 7 indicates that derivatives and medicinal products are the most commonly seized *Saussurea costus* products. In cases where the purpose of these illegal or irregular shipments was recorded, around 70% were intended for personal use, with these cases often involving relatively low volumes of product (e.g. 1 kg or less). A small number of seized commercial shipments contained considerably larger volumes (tens or hundreds of kilos), although the number of large seizures recorded in the database has declined since 2010. The extent to which these trading and compliance patterns may be reflected within online marketplaces remains unclear.

FIGURE 7:

Numbers of legal and seized shipments of *S. costus* products recorded by the CITES trade database, 2008–2018



***Saussurea costus* roots, sliced to reveal their cross section**

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Appendix B. Keyword lists

As detailed in the Methodology (section 5), a collection of keywords and relevant terms for each plant group were used to focus the search software on the right areas of online content. As well as the species' valid Latin names, keywords included relevant subspecies, spelling variants and Latin synonyms. Synonyms are of particular importance to botany, as many species are referred to by multiple Latin names owing to the complex history of plant taxonomy. Terms relating to trade and the behaviour of online actors were then added by both the criminologist and computer science teams. Any words likely to result in a high number of false positive results were blacklisted.

The initial sets of keywords generated for each of the plant groups are displayed below. Within these, '+' indicates that all terms are required (in any order), and quotation marks indicate that an exact sequence is required. Usually, the search software was not directed to find exact sequences, as it frequently requires a combination of keywords from different areas of a post to identify content of interest.

TABLE 11:

Keywords for selected *Ariocarpus* species

Names	Excluded terms	Forum terms	Buy/sell terms
Ariocarpus	seed(s)	forum	web+buy
Ariocarpus+agavoides		thread	internet+buy
Ariocarpus+bravoanus		topic	buy
Ariocarpus+hintonii			buy+online
Ariocarpus+kotschoubeyanus			order
Ariocarpus+kotschubeyanus			sale
Ariocarpus+kotschobeyanus			selling
Ariocarpus+kotsch			purchase
Ariocarpus+confusus			live plant
Ariocarpus+albiflorus			swap
Ariocarpus+retusus			
Ariocarpus+scaphirostris			
Ariocarpus+ scapharostroides			
Ariocarpus+scapharostrus			
Ariocarpus+trigonus			
"Tamaulipas living-rock"			
Tamaulipas living rock			
"Nuevo leon living-rock"			
Nuevo leon living rock			

TABLE 12:

Keywords for selected *Euphorbia* species

Names	Group-specific terms	Forum terms	Buy/sell terms
Euphorbia+ambovombensis	seeds	forum	web+buy
Euphorbia+cremersii		thread	internet+buy
Euphorbia+rakotozafyi		topic	buy
Euphorbia+viridifolia			buy+online
Euphorbia+moratii			order
Euphorbia+antsingiensis			sale
Euphorbia+bemarahensis			selling
Euphorbia+multiflora			purchase
Euphorbia+cylindrifolia			swap
Euphorbia+tuberifera			live plant
Euphorbia+decaryi			
Euphorbia+ampanihyensis			
Euphorbia+robinsonii			
Euphorbia+spriosticha			
Euphorbia+quartziticola			
Euphorbia+tulearensis			
Euphorbia+francoisii			
Euphorbia+parvicyathophora			
Euphorbia+capsaintemariensis			
Euphorbia+cap-saintemariensis			
Euphorbia+handiensis			
Cardón de Jandia			
Euphorbia+lambii			
Tabaiba Amarilla de Tenerife			
Euphorbia+bourgeana			
Euphorbia+stygiana			
Euphorbia+santamariae			

TABLE 13:

Keywords for *Saussurea costus*

This species has a particularly high number of common names. Of these, the names that preliminary searches suggested were of greatest relevance to trade on the online platforms were included in the final keywords list. Mu Xiang is a term for *S. costus* used within TCM.

Names	Group-specific terms	Forum terms	Buy/sell terms
Saussurea costus	root	forum	web+buy
S. lappa	roots	thread	internet+buy
Auklandia lappa	oil	topic	buy
A. costus			buy+online
Kuth			order
Aucklandia			sale
Saussurea			selling
Costus			purchase
Kustha			swap
Kut			
Postkhai			
Kur			
Kot			
Kostum			
Sepuddy			
Koshta			
Kotu			
Aplotaxis lappa			
Theodorea costus			
Costus+root			
Costus+oil			
Saussurea+lappa			
Saussurea+incense			
Saussurea+Joss stick			
Costus+Incense			
Costus+Joss stick			
Lappa+incense			
Lappa+Joss stick			
Mu Xiang+Costus			
Mu Xiang+Lappa			
MuXiang+Costus			
MuXiang+Lappa			

Saussurea costus
medicinal crop in China

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Disclaimer 2:

The investigations into online trade performed during this study are for research purposes only. To protect the privacy of individuals and organisations all results are pseudonymised, and any resemblance to real people or organisations is entirely coincidental.

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