Quantifying the illegal high-value rosewood trade and criminal trade networks in the Greater Mekong Region

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ABSTRACT

Illegal trade network patterns may be explained by geographic, economic and environmental factors, and may change over time. Rosewood is one of the most valuable taxa in the illegal and unregulated wildlife trade, and we focus on its trade in the Greater Mekong Region. Using media sourced seizure data, we firstly present an empirical depiction of the confiscations of rosewood throughout Thailand over a seven-year period (2013–2019) based on 2274 seizure reports; mapping geographic locations, trends over time, transport route within Thailand and import and export into other Greater Mekong Region countries. We test factors explaining seizure patterns using a Generalised Linear Model and conducted basic analysis on suspect data using suspect nationality. We find that geographically timber crimes occur throughout Thailand, but especially in border areas with Cambodia and Laos; the final destination in most cases appears to be China. Suspects are backed by complex criminal networks. Geographic factors were the strongest in determining hotspots of seizure activity suggesting timber trafficking occurred mostly in border provinces. Our findings provide general support for the argument that rosewood trade network is transnational in terms of sourcing and consumption as well as actors involved. It raises important questions about crimes against the environment and the importance of domestic legalisation and how international regulations are effective in the protection of rosewood species. More generally, our study illustrates the ways online sourced seizure data can be used to provide an initial quantitative assessment of the rosewood trade network patterns.

1. Introduction

1.1. Illegal trade in rosewood

The illegal wildlife trade is a multibillion-dollar industry and is seen as one of the drivers of the current biodiversity crisis ('t Sas-Rolfes et al., 2019; Morton et al., 2021; Hughes, 2021). Over the past decade, the illegal trade in wildlife, which includes poaching, harvesting, transporting and collecting of plants and animals, dead and alive, is ranked among the most lucrative illicit economies, on par with illegal drugs and humans and arms trafficking (Wyatt, 2009; Wyler and Sheikh, 2013; Barber-Meyer, 2010; Fukushima et al., 2021). It is increasingly recognized that the illegal wildlife trade is linked to organized crime (UNODC, 2013). Trade occurs at different spatial scales, which affects the survival of a range of species with long-term negative impacts on the wider environments, including us humans (Scheffers et al., 2019). The illegal movement of wildlife across borders enables us to characterize the illegal wildlife trade as a transnational crime, defined by 'either a cross-border criminal who perceives opportunities to commit crimes beyond national borders or by the cross-border transfer of illegal commodities' (Albrecht, 2011). International protection and regulation is covered by international bodies, such as INTERPOL and the UN Office on Drugs and Crime, as well as specific conventions such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (CITES, 2020).

The trade in elephants, tigers, rhinos and pangolins and their products, and the effect it has on remaining populations, is commonly reported in the media. Each of these taxa can be seen as a poster child for the illegal wildlife trade. However, unbeknownst to many, in terms of monetary value the trade of illegal wood and timber products tops the list. Specifically, rosewood is the world's most trafficked wildlife product. It represents over 40 % of the number of seizures over the period 2009–2013 and 32 % in terms of monetary value over the period 2014–2018 (UNODC, 2016, 2020). Since the early 2000s, rosewood species have been under significant threat with increasing demand from China (Innes, 2010; Dumenu, 2019; Vardeman and Runk, 2020;

Arunkumar et al., 2021; Gaisberger et al., 2022; Bandoh et al., 2022; Zhu, 2022). 'Rosewoods' are the term used to generally describe richly-hued hardwoods. Within the group of hard redwoods, there exists a subgroup, in the commercial trade referred to as 'hongmu' (also spelled as hong mu, hóng mù, 红木) which comprises 33 rosewood species that are found distributed across Africa, Latin America and Asia. The characteristic of *hongmu* is its deep-red colouring, aromatic scent and distinctive durability against termites and rot (CITES, 2016). Rosewood is a broad trade name that refers to a number of species (UNODC, 2016); therefore, it may encompass both *hongmu* species and non-*hongmu* species as well as CITES listed species and non CITES-listed species.

In the past decade, there has been a spike in the demand for rosewood, particularly because of China's emerging and rapidly growing group of wealthy middle-class elites and the Chinese government's commodification and lax import laws of rosewood furniture and items (Schuurman and Lowry II, 2009; Treanor, 2015; EIA, 2016). In China, buying rosewood is not simply an act of "conspicuous consumption" but it is a revival of a cherished imperial history, a time when elaborate rosewood furnishings were commissioned by emperors. Its value is both cultural and speculative. As such rosewood furniture is in high demand with China's nouveau riche (Zhu, 2022). Unsustainable logging and unregulated trade have led to the commercial decline of several species such as fragrant rosewood or huang hua li (*Dalbergia odorifora*) in China (EIA, 2016) and Madagascar rosewood (*D. baronii*) (Schuurman and Lowry II, 2009; Innes, 2010; Wilmé et al., 2020).

The international trade of rosewood is managed under the CITES treaty, mandated to regulate and ensure sustainable level of harvest (Waeber et al., 2019). Prior to the new popularity of rosewood, only one species, Brazilian rosewood (*D. nigra*) had been regulated under CITES as an Appendix I species (Waeber et al., 2019). In 2013, a highly prized species in southeast Asia, Siamese rosewood (*D. cochinchensis*), was included as an Appendix II species, along with Malagasy species of *Dalbergia* and *Diospyros* (ebony) (EIA, 2014; Waeber et al., 2019). As an Appendix II species, it is permissible to be traded internationally with proper permits (UNODC, 2016). In 2016, further listings were accepted to include all ~300 species of *Dalbergia* under Appendix II (CITES, 2016).

However, when considering specifically *hongmu* and its regulation under CITES, the international trade in only eight of the 33 species is regulated. Despite increased international regulation and attention, the illicit *hongmu* trade still thrives in many places, mostly, in tropical and developing nations. This is due to poor governance, corruption, limited resources of law enforcement agencies, and the fast-moving nature of harvesting unlisted or unprotected replacement species by traders (Reeve, 2015; UNODC, 2016; EIA, 2020; Kansanga et al., 2021; Arunkumar et al., 2021). An example of this is in Madagascar, where despite the uplisting in protection of Madagascar rosewood (*D. baronii*), over-exploitation of rosewood timber has been exacerbated by government instability and loopholes in law enforcement, leading to a 'rosewood massacre' (Schuurman and Lowry, 2009; Barrett et al., 2010; Randriamalala and Liu, 2010; Waeber et al., 2019; Wilmé and Waeber, 2019, Wilmé et al., 2020). Illegal logging of rosewood inside national parks continued, leading to several imperilled rosewood species in Madagascar (Zhu, 2017, 2022).

1.2. Theoretical framework of illegal and unregulated trade

This study builds on the fundamental frameworks and analysis of green criminology. The establishment of green criminology has been gaining research interest in the recent years with the aim to address the consequences of environmental crimes on humans, non-humans and society (Lynch, 1990, Lynch and Stretesky, 2014, White, 2013). The increased transnational nature of environmental crimes creates threats to security of the global community (Elliot, 2012). Specifically in terms of the illegal wildlife trade, green criminology has been used as the guidance to better understand the motivations of natural resource

exploitation specific to domestic case studies (Zimmerman, 2003; Warchol, 2004; Petrossian et al., 2016; Pires, 2012; Cao Ngoc and Wyatt, 2013; Wyatt, 2013). This approach has also been used to contextualise illegal activities related to illegal wildlife trade, such as better understanding of wildlife poaching (Rizzolo et al., 2016) or sentencing patters of environmental crimes (Cochran et al., 2018; Ni et al., 2022).

Seizure data can be used to fill data gaps in trade patterns of illegally traded species, including, elephant ivory (Underwood et al., 2013; Yeo et al., 2017), pangolins (Challender et al., 2015), bears (Gomez and Shepherd, 2018), otters (Siriwat and Nijman, 2018), songbirds (Indraswari et al., 2020) and marine mollusks (Nijman, 2019). Acting as small pieces of puzzles, information obtained from a single seizure has the potential to reveal important nodes within an organized crime network (Reeve, 2002; van Uhm, 2016; Paudel et al., 2022). Open-source seizure data sets can reveal current (and sometimes can predict future) spatial and temporal patterns (concerning origin, transit, destination) as well as reflect on the magnitude (species, type of species) in a fast pacing and ever-changing trade (LeClerc and Savona, 2017). The preference to use data which are freely accessible also coincides with the novel approaches to study such trade activity (Lopes et al., 2019, Paudel et al., 2022). With illegal trade in rosewood being viewed with less seriousness, for example, when compared to illegal trade in animals, seizures are reported continuously in the global media (Nijman et al., 2022). We here aim to contribute to the criminological research on wildlife trafficking by using seizure data to fill data gaps on the pathways involved in the illegal rosewood trade, on the actors involved, and on the locations and processes used.

1.3. Spatial and temporal analysis of seizure data

In this study we aim to demonstrate the transnational nature of rosewood crimes in parts of the Greater Mekong Region, in particular Thailand, but also Myanmar, Lao People's Democratic Republic (hereafter Laos) and Cambodia. We pay particular attention to the shift from national (domestic, within Thailand) to regional (Great Mekong Sub-regions, i.e., the countries neighbouring Thailand) and international trade (including China and other East Asian countries). We use information obtained from media seizure reports to quantitatively investigate the rosewood trade, and reveal current spatial (origin, transit, destination) and temporal patterns, as to document the scale of trade. Details on pathway information, suspect information and arresting agencies were also obtained from the seizure reports to illustrate the *modus operandi* of traders. We aim to explain the number of seizures by economic, environmental and geographic factors using a Generalised Linear Model, and highlight the usefulness of online sourced seizure data for an initial quantitative assessment of the illegal rosewood.

2. Methods

2.1. Study species

Asia is home to 17 of the 33 species listed under China's *hongmu* standard. One of the key hotspots for rosewoods is the Greater Mekong Region. This region is home to *Dalbergia* and *Pterocarpus* species. Here, we focus on three rosewood species found throughout the region, i.e., Siamese rosewood, Burmese rosewood (*D. oliveri*) and Burmese paduak (*P. macrocarpus*) (Table 1). These represent one of the most coveted *hongmu* species (Siamese rosewood) and two lesser-known species that are, or could be considered, substitute species. Importantly, all three figure in the 33 species of *hongmu* list published by the Chinese Government.

In the Greater Mekong Region, harvesting of rosewood timber to satisfy the demand in China has skyrocketed since 2000. While *hongmu* species are found in South America, Africa and Asia, the Greater Mekong Region (particularly Myanmar and Lao PDR) alone accounts for up to 70 % of Chinese markets imports of *hongmu* (EIA, 2014; Gaisberger et al.,

Table 1
Details on the three rosewood species studied, including natural range states, IUCN listing, CITES listing, domestic protection, and estimated market values.

Species	IUCN Red List, CITES status	Natural range state	Protection Thailand	Protection Myanmar	Protection Cambodia	Protection Lao PDR	Price per cubic m[3a]
Siamese rosewood (*D. cochinchinensis*)	Vulnerable, Appendix II (2013)	Cambodia, Laos, Thailand, Vietnam	Yes	Not a range country	Yes	Yes	$93,000
Burmese rosewood (*D. oliveri*)	Endangered, Appendix II (2017)	Cambodia, Laos, Thailand, Vietnam, Myanmar	Yes	Log export ban	Log export ban	Yes	$9200
Burmese padauk (*P. macrocarpus/ P. pedatus*)	Not listed	Cambodia, Laos, Thailand, Vietnam, Myanmar	Yes	Log export ban	Yes	Yes	$6300

[a] Source: Anonymous (2017).

2022). At the peak of the 'rosewood boom' in 2014, China imported over US$2 billion in *hongmu* species (Treanor, 2015). The increased market value of rosewoods (a tonne of unworked rosewood has an estimated value of between US$10,000 to US$50,000 depending on the species and in what part of the trade chain the timber is: Nijman et al., 2022) has led to an increase in illegal harvesting activities and enforcement actions. Illegal logging remains prevalent in pockets of forest with rosewood trees (be it inside protected areas, public or private land), despite increased law enforcement (Dwyer et al., 2016; Singh, 2014; EIA, 2016; Arunkumar et al., 2021). In many cases, high levels of corruption along the supply chain, ranging from local communities, middlemen and traders to government officials, facilitate the illegal trade (EIA, 2014; Kansanga et al., 2021). There is evidence to support that loggers are backed by organized syndicates, reflective in the 'logging armies' crossing borders to log and transport timber, setting up 'logging factories' in protected areas, and a weaponization along the trade chain (Treanor, 2015; Dwyer et al., 2016; EIA, 2014; Ferriss, 2014; EIA, 2020). As target species became more difficult to obtain, shifts to other, initially less desirable, *hongmu* species, occur. Thus, a depletion of Asian rosewood led to a move to import West African species, and kosso (*P. erinaceus*) accounted for 83 % of imports into China in 2020 (Treanor, 2015, 2022). In recent years, the slowdown of the global rosewood market has been attributed to several factors, including global economic slowdown (Waeber et al., 2019), decrease in quality of imported timber, increased Chinese enforcement efforts to reduce illegal timber imports (Hoare, 2015; Jiao et al., 2021), and an increase prosecution (Ni et al., 2022). In 2020, China amended its Forest Laws prohibiting the sale of timber from illegal sources within China; this led to several high-profile raids aimed at curbing the illegal timber trade.

2.2. Data collection

Because of the clandestine nature of the illegal wildlife trade, it can be challenging to obtain data on species, volumes, turnover, and trends over time (Barber-Meyer, 2010). To overcome this we use open-source media reports as the main source of data on the illegal trade in rosewood. Media news reports related to rosewood seizures were searched on online news agency websites in a snowball sampling approach. Thailand ranks 115/180 countries in terms of the World Press Freedom Index 2022, and a major challenge deals with the freedom of reporting any criticism on the government; from our reading of seizure reports we do not get the impression that there are any serious obstacles in reporting on these seizures (other than delays, see below). We focused on ten news websites in Thailand that were monitored over the period 2016–2019 (see Supplementary Table 1). For each year, seizure reports were collected at the end of the year, except for the first year of data collection in 2016 when reports were retrospectively collected for the previous three years. Searches were conducted in reverse chronological order. Search terms included rosewoods local species names (*phayung/ chingchan/pradu*) + 'trade' (*kah phayung*), 'seizures' (*jub mai phayung*) and 'transport' (*khon mai phayung*). Searches were carried out entirely in Thai language. While many seizures are reported by the media soon after the actual seizure has been made, during our research it became apparent that some seizures only were made public months after the

actual seizure was made. This could be either because the legal procedures had progressed (e.g., a suspect was brought in front of a judge; this was reported and while doing so information of the seizure was made public as well) or because information surfaced following another seizure (e.g., in publicizing a seizure made the day before, the authorities also provide information on a previous seizure that until then had not been made public). We thus continued to monitor the news sites during 2020 but focused only on seizures made between 2013 and 2019.

Details of the seizures within the news reports were collected, including, where possible, date, location (one of 878 districts and 76 provinces), number of logs and/or volume seized, references to border crossings or border posts with Myanmar, Laos and Cambodia, and trade routes. Each report was classified according to type. First, timber classified as 'storage' includes timber that was hidden in storage or stored within private properties, facilities or warehouses. Timber classified as 'en route' was defined as timber seized during transport whether in cars, boats, cargo containers, or seized next to roadside or riverbanks. The third category is 'protected areas', which are timber seized within or bordering government protected areas, wildlife sanctuaries, or government facilities in these areas. The final category is 'on-the-spot logging' which includes seizure reports of rosewood trees being cut down in non-protected areas, or public areas.

The species and volume or number of logs seized was recorded. Each confiscated piece of timber is usually reported as a unit of 'log'. Volume could also be reported, though not as frequently used. Details on arresting agencies were also recorded, such as the government agency leading or coordinating the seizure. Each seizure report was considered an independent case and checked for duplication. For any duplication, the report with the most details was selected (cf. Nijman, 2015).

Information on suspects that were openly reported were collected, and were limited to details on nationality, and qualitative descriptions of their operative pathways such as, geographic origins on where the logs were sourced, immigration statuses of suspects, and their intended details of their operations. Details related to suspect identity, such as name, age, gender, and home address, although reported, were not collected.

We obtained independent data from the Department of National Parks, Wildlife and Plants (DNP), on the volume of wood (m^3) that was seized, and the number of seizures that took place, for each of the years 2013 to 2017. These seizures include all types of wood and not just rosewood and were far less frequently reported in the media. We used these data to test the veracity of media reports on rosewood seizures we used in our analysis.

2.3. Mapping pathways

Pathways were mapped out to provide a glimpse of the various trade routes used for the rosewood smuggling; for this we used the qualitative description from the content reported in the seizure reports. These routes were copied and the contents were analysed and broken down into three main parts that comprised of geographic location (origin or intermediate provinces used), transport method (the transport means within Thailand) and exit (the transport means exporting logs from Thailand and to its final destination). News reports that had complete information on routes used were recorded and tallied.

2.4. Statistical analyses

We pooled data obtained for the trade of the three species of rosewood in Thailand. The primary units of analyses used are (1) the number of seizures and (2) the number of logs seized. Most commonly in reporting, the term to describe the logs is 'ton' (ท่อน) which when translated literally means a piece that has been cut. This is often the term used in reporting the numeric unit (count) of logs seized. It refers to timber in general, regardless of its form (e.g., raw, processed or debarked logs), or size (whole trunks, part of trunks). In its processed forms, timber can also be referred to as veneer sheets and squares, though this is less common. All these pieces (logs, sheets and squares) were considered under the number of logs. While the 'count' of the logs is most commonly reported, in some cases, information on the volume of timber seized (m^3, or tonnes (ตัน)) is also provided.

The provincial-level analysis was conducted to explain the number of seizures reported. To explain the variation we observed at the provincial level, and to identify any possible pattern, we created a GLM model that include the variables representing geographic, economic, ecological factors (Table 2). All data were log-transformed prior to analysis if it was not found to follow a normal distribution. Monetary values of timber seized, and payments made were reported in Thai. In the monitoring period of 2013 to 2019, the US$ ranged from 29.93 to 36.04 Thai Baht; an exchange rate of US$ 1 = 33.21 THB was used. Statistical analyses were conducted in R Program (R Core Team, 2020).

3. Results

3.1. General and spatial patterns

In the seven-year period from January 2013 to December 2019, a total of 2258 seizure reports of the three rosewood species were recorded from ten news agencies (Table 3; Fig. 1). Seizure reports occurred in 63 of 76 provinces in Thailand, with most of it originating in Ubon Ratchathani province (n = 363) followed by Mukdahan and Sri Sa Ket province (both n = 224), all situated in the northeastern region of Thailand (Fig. 1d). A relatively large number of seizures were made in provinces bordering Cambodia, followed by Laos, relatively few with the border with Myanmar, and very few with Malaysia (none of the three species we focus on occur naturally in Malaysia).

The volumes of logs seized ranged from 1 single piece to 15,753 logs, totalling 185,837 logs seized reported in news outlets (Table 3; Fig. 2a). For 256 seizures the number of logs was not reported, other than that it involved large volumes of trees or cargo shipments, and the real number

of rosewood logs seized over this period is certainly higher than the 185,837 logs we base our analysis on. Broken down into seizure types, the most common category of seizure was caught in transport (37 %; 862/2351), followed by storage-based seizures (35 %; 833/2351), protected areas (17 %; 396/2351), and on the spot logging (11 %; 260/2351). Seizures of rosewood in storage, en route and from protected area all showed a decrease over time and seizures made of rosewood during on-the-spot logging peaked between 2016 and 2018. Overall, there was a fluctuation in the number of seizures reported over the monitoring year period (linear regression: R^2 = 0.55; $F_{1,5}$ 6.14, p = 0.056). While the Department of National Parks, Wildlife and Plants seizures include more than just rosewoods, we found a good agreement between these seizure data and data we extracted from media reports (media reports on number of logs vs DNP volume of logs, all log-transformed, Pearson's R = 0.872, n = 5, p = 0.054; media reports of rosewood seizures vs reports of all timber seizures from DNP, R = 0.917, n = 5, p = 0.028) (Fig. 2b).

The variation in the number of seizures for each province was best explained by a combination of geographic (distance to border), economic (GPP), and environmental (% forest cover) factors (Table 4). For Siamese rosewood, the distance to the border to each of the provinces was found to be the only statistically significant predictor (glm, $T_{45, 42}$ = −3.41, p = 0.0014), with more seizures closer to the border. For Burmese rosewood and Burmese padauk the number of seizures was positively related to the amount of forest (glm, $T_{37,34}$ = 2.58, p = 0.015 and $T_{48, 45}$ = 2.41, p = 0.02, for Burmese rosewood and Burmese padauk, respectively). The distance from the geographic centre of each province to the border was the only statistically significant predictor of the total number of seizures of the three species combined (glm, $T_{50,57}$ = −3.98, p < 0.001).

3.2. Modus operandi and trade pathways

We obtained information on the smuggling routes from 487 seizure reports, including for instance, where the timber was logged, where it was travelling from and to, and the intended end destination. Only 18 seizure reports noted that the rosewood was for domestic consumption. The way how rosewood was obtained and trafficked differed greatly. There were cases where single or a small number of loggers entered a protected area, sometimes from across the border from Cambodia or Laos, to obtain rosewood. There was also evidence of more planned operations whereby organized groups entered protected areas 30 to 40 people at a time (again this could be from within Thailand or from across the border). Groups of smugglers would bring monthly supplies of food, camp in the forest, and set up a supply chain system with goods coming into the area and rosewood moving out.

Information included in the seizure reports indicated that vehicles were modified to carry and conceal large loads of timber. There were instances where networks of teams working together with front and/or back vehicles were present to scout for the central vehicle of roadside checkpoints and/or serve as escape vehicles. There were a few cases where seizures were made en route, with large trucks being used to transport wood. Reports explicitly stated that logs were illegally harvested from certain National Parks, such as the Dong-Phayayen Forest Complex that encompasses one Wildlife Sanctuary and four National Parks.

3.3. Suspects

Suspects were apprehended at the scene in 44 % (n = 1002/2258) of seizures reports (Table 5). For 1689 suspects their nationality was included with 69 % being Thai (n = 1176). Almost a third of the suspects came from neighbouring countries including Cambodia (25 %, n = 427), Laos (4 %, n = 72) and the Karen ethnic community (Myanmar) (<1 %, n = 2). Comparing with the number of foreign nationals living in Thailand, it becomes clear that Cambodians and Laotians are overrepresented, and the Burmese are underrepresented as apprehended

Table 2
Predictor variables included in the GLM to predict and explain the number of seizures per province (with, where appropriate, the approximate geographic centre of each province used for analysis).

Predictor variable	Proxy
Seizures	Number of seizures
Logs	Number of logs seized
Provincial data	Two variables were used as provincial factors. Province 'size' and province 'population' is included.
Spatial	Two variables were used as spatial geographical factors. A variable for 'border' was included, if the province is located at the border of Thailand, whether it is next to another country, or with water-borders. The second variable included was 'region', classified in the 7 regions of Thailand: Bangkok (Including Metropolitan region), central, eastern, northeastern, northern, southern, and western.
Temporal	Number of seizures over time for Thailand and individual provinces
Economy	Gross provincial product - GPP per capita for 2017 (in Thai baht) (NESBD 2017)
Environment	Provincial forest cover (national parks and forest areas) - forest area (%) for each province (DNP 2014)

Table 3
Total number of reports, logs seized and total volume (where data available) from the period of 2013 to 2019.

	2013	2014	2015	2016	2017	2018	2019	Total
Total reports	378	624	330	287	214	231	195	2258
Total logs	42,104	63,487	44,748	13,147	8193	8160	5998	185,837
Total vol (m³)	279	1147	432	219	153	743	66	479

suspects. Where renumeration information was available (n = 183), agreed financial payments ranged from US$15 to US$1204 per person, averaging from US$171±103 for seizures made in storage facilities to US$282±229 for those seizures made en route.

3.4. Arresting agencies and legislation

In total, 20 government agencies reporting to six ministries or major government bodies were involved in rosewood crimes and arrests (agencies were listed by name in n = 2187 reports) (Fig. 3). When seizures were carried out by single agencies (this happened in 38 % of the cases), the Royal Thai Police (RTP; which includes the police, traffic police, Royal Thai Immigration, Border police, NRECD) was responsible for 23 % (n = 504/2187) of the seizures. The Environmental government agencies (Department of National Parks, Wildlife and Plant Conservation and the Royal Forestry Department) were responsible for 6 % of the seizures (n = 132/2187). Almost a third (31 %) of the seizures were led by two government agencies. Seizures carried out bilaterally between the police and environmental agencies (DNP/RFD) accounted for 8 % (n = 207/2187), followed by bilateral seizures between military agencies and police at 7 % (n = 159/2187). Seizures carried out by three or more agencies accounted for the remaining 31 % with the highest cooperation between the police, the military and the DNP/RFD (12 %; n = 256/2187). Most government agencies operate throughout Thailand, but some have authority over a geographically restricted area. The Mekong Riverine unit works specifically in the Mekong Region, while the Water police (harbour police) deals with both Mekong Region and Gulf of Thailand.

Often, seizure reports refer to the legal penalties associated with the possession of prohibited timbers, mainly, references to the domestic articles within the Thai constitution in the timber laws (n = 551). In only nine seizure reports, CITES regulations and/or penalties were mentioned, and one single report mentioned a bilateral cooperative enforcement action with Cambodian authorities.

4. Discussion

4.1. Modus operandi of the rosewood trade

Based on solely online seizure data, and assuming that seizure data reflect levels of trade, we show that the trade of three rosewood species in the Greater Mekong Region is continuing, with higher levels of activity at the beginning and middle parts of our study (i.e., prior to 2015) than in later years (2016 and beyond). The rosewood trade in Thailand is predominantly sourced in Thailand and aimed for international trade. Thailand is both a key source and transit country, with most of the seizures taking place along the Cambodia and Laos border of rosewood that is being illegally exported from Thailand. While we expect these border regions to feature highly in international trade, a preponderance of seizures in these regions may be in part explained by a higher military and border agency presence. Although many more seizures report the direction of movement outwards towards international borders, few report movement inwards, mainly to Bangkok or Chonburi province. This is because of the large city may be easy for more concealment, but also because of the fact that large ports in the cities or towns may be used to ship the logs out of the country in large volumes. The consumer markets for Siamese and Burmese rosewood are outside Thailand. In contrast the illegal trade in Burmese paduak is also driven by a domestic,

Thai, demand. While the seizure reports do not allow us to check the veracity of the species identification (Siamese rosewood could be labelled as Burmese rosewood and vice versa), given the significant price differences and hence seriousness of the crimes, we do expect authorities to have made an effort in identifying this correctly. Burmese rosewood was cited by many sources as the replacement species for the Siamese rosewood, which is to be expected as the latter is increasingly difficult to source.

Burmese paduak was in part for domestic use and here the routes taken, and the locations where seizures are made, differed from the other two rosewood species. Most of the seized rosewood, and especially Siamese and Burmese rosewood, was destined for the Chinese market, and Cambodia and Laos act merely as transit countries rather than end destinations. Rosewood is smuggled out of Thailand by crossing the Mekong River, through cargo shipments, or by means of other sea vessels crossing the Gulf of Thailand.

The key areas of transport routes of the country predominantly are situated in the north and northeast region of Thailand along the Mekong River, and this is consistent with previous findings (EIA, 2014, 2016; Treanor, 2015). In 2014, Laos and Cambodia were ranked first and tenth in exporting rosewood logs by volume to China through official trade channels (Treanor, 2015). We show that the illicit rosewood trade network is transnational by nature and involves actors and funders that are of Thai and foreign nationality.

Seizure reports demonstrate that the main transport method within Thailand is by means of modified makeshift vehicles. Across the Mekong River, long-tailed boats are used to move logs across the border. Shipping ports such as Lam Chabang Port in Chonburi and Bangkok Port, were used to export large cargo containers of illegal timber directly to China through the Gulf of Thailand. Due the large volume of timber shipped, in some cases, Bangkok's Metropolitan Area offers a gateway for rosewood to be shipped. The crime-syndicate nature of the trade is reflected by the observation that suspects were frequently accompanied by several other cars to scout for authorities, as well as the fact that suspects often had large sums of money on them.

Temporally, seizure activity increased immediately following the inclusion of Siamese rosewood on the appendices of CITES. The patterns observed in this study using media reports of seizures matches that of official records of Thailand's seizure data of all timber species. The peak of seizures found both in this study and in government records show that 2014 is the year where CITES listing is officially implemented after the 2013 Convention of Parties approved listing Siamese rosewood as an Appendix II species. Trade bans are linked to stimulating wildlife trade, in cases in countries where capacity, governance and enforcement may be limited to implement stricter blanket regulations, resulting with trade being directed illegally (Rivalan et al., 2007; Challender et al., 2015). Understanding and determining the motivations and drives along participation in the supply chain will enable governments to utilise limited resources in a targeted manner to combat illegal trade (Santos et al., 2001).

What is clear in this study is that a collaborative and integrative approach is needed between local, national and international enforcement bodies. Illegal loggers and wood smugglers cross green borders, with few cases reporting successful arrests of suspects, or more importantly, successful investigation of kingpins or financial backers. According to the Thai government, <10 % of suspects are arrested (Anonymous, 2016). The actors involved are not only Thai, but also of other neighbouring Greater Mekong Subregion countries, especially

Government agencies involved posed for a picture.
Example: pictured here includes Border Patrol Police, Royal Thai Marine Police, Royal Thai Navy, Royal Thai Customs, Police, Provincial authorities, Surasak Forces (Army)

Headline with leading agencies
Example: "Royal Thai Navy seizes rosewood wile being transported to nieghboring country, worth millions"

Transport methods highlighted
Example: "Transported via boats towards neighboring country"

Date and time
Example: 29 May 2015 at 13.30

Volume/Numbers seized
Example: "12 logs and 5 sheets" without any markings

Further details on pathways
Example: "Intel provided that timber will be transported near the river bank to be transported across pier at Bang Sai Noi district in Mukdahan Province and authorities canvassed the area until a suspected vehicle arrived"

Further details on suspect
Example: "Suspect narrowly escaped, possibly familiar with the area, and escaped into the local forest area"

Further details on value
Example: "Based on the diameter of the seized logs around 60 cm, the age of the tree could be around 120 years old, valued at around 1 million baht. All seized items were sent to Mukdahan Police Station and further investigations will be carried out"

Search tags
Example: "Rosewood seizure / Illegal rosewood / Rosewood 120 years/ Mekong river/ Navy Mukdahan"

Fig. 1. An example of a screen shot of news demonstrating the boilerplate format of a news article. Each news article usually comprises of information on the agencies involved, volume of logs seized, geographic location and (intended) trade pathways; suspect information is often reported on as well.
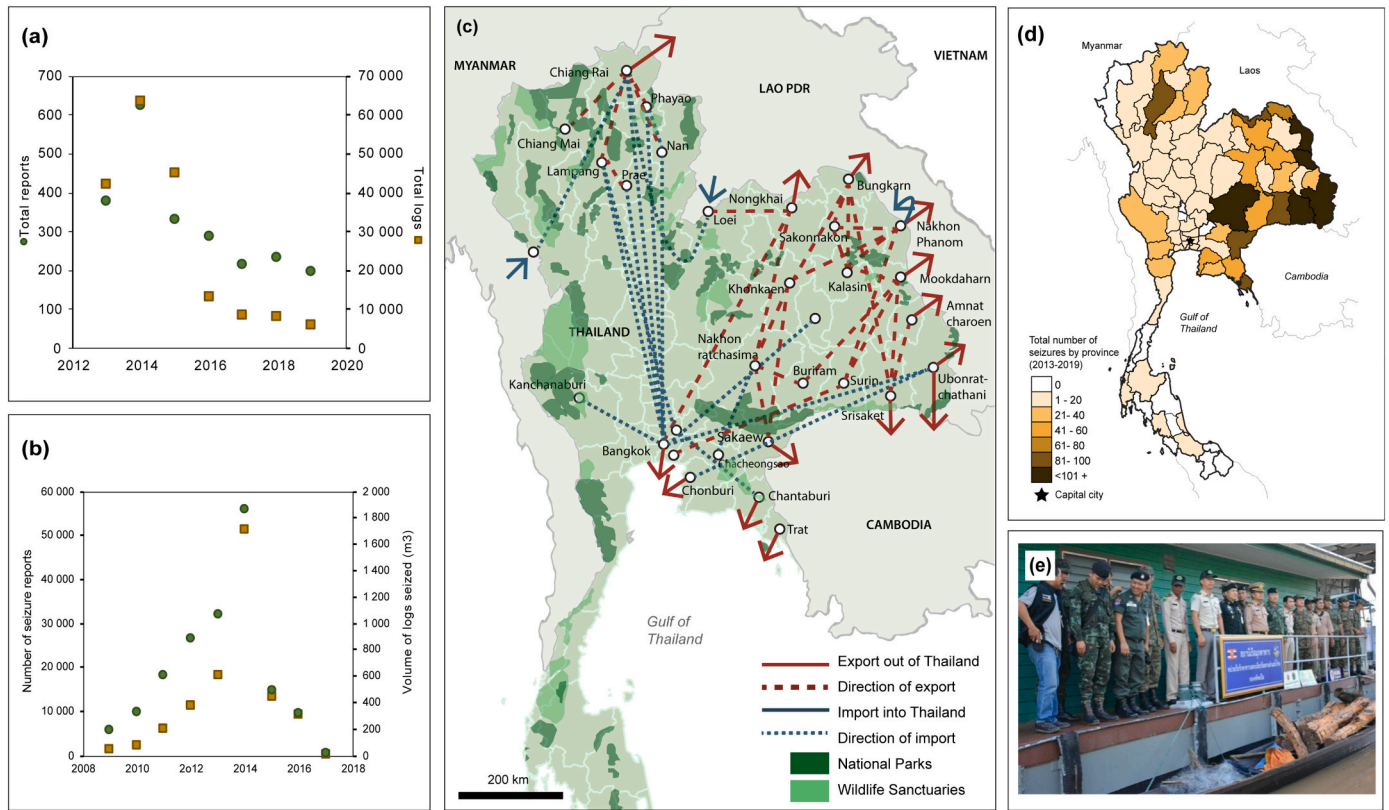
Fig. 2. (a) Total number of seizure reports and total logs seized from the period of 2013 to 2019. (b) Total number of seizure reports and volume of logs seized from the period of 2009 to 2017 as reported by the Department of National Parks, Wildlife and Plant, (c) trade pathways mapped based on the information extracted from news seizure reports (n = 487). The lines represent the direction of movement – inwards (dashed red line for domestic movement, solid blue line for international movement) and outwards (dashed red line for domestic movement, solid red line for international movement). Symbols at the border represent the intended mode of transport used to move logs out of the country. (d) Map of the number of seizures for all three rosewood species combined for the entire study period, (e) example of a seizure of rosewood logs on a boat in Trat province. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Model outputs and significances for factors included in the Generalised Linear Model used to predict the number of seizures per province for the total number of seizures.

Factor	GLM coefficients and p values
Province size	t value = 0.855, p = 0.396
Population	t value = 0.892, p = 0.376
GPP	t value = −0.548, p = 0. 586
Provincial forest percentage	t value = −1.041, p = 0.302
Region	t value = −1.792, p = 0.078
Border	t value = 2.785, p = 0.007

Cambodia and Laos.

4.2. Considerations for Thailand's new timber laws

Thailand hosted the Conference of Parties to CITES twice (in 2004 and 2013) and one of the perhaps more remarkable findings of our study was the almost complete absence of reference this or other international treaties or multilateral agreements that Thailand has signed. We expected, given that Siamese and Burmese rosewood are both listed on the appendices of CITES, and given that a substantial part of the seizures concerned rosewood intended for international markets, that frequent reference would have been made to this Convention. The observation that this was not the case suggests that Thailand considers the trade in, and seizures of, rosewood largely a domestic issue. This may reflect the complex relationship between CITES and national governments and law

Table 5
Details on suspects, including the population by nationality in Thailand, the number of suspects expected according to population ratio, the number of suspects expected, and the interpretation (substantially less, less, more, substantially more).

Nationality	Million in Thailand	Suspects (expected)	Interpretation
Thai	59.76	1176 (1614)	Substantially less
Myanmar[a]	1.29	2 (35)	Less
Cambodia	0.28	427 (8)	Substantially more
Lao PDR	0.22	72 (6)	More
China	0.14	5 (4)	
Vietnam	0.02	5 (1)	
Other, incl. Stateless	0.63	0 (17)	Less

[a] This includes the Karen, a largely Burmese group and a proportion of whom have settled more or less permanently on the Thai side of the Thai-Myanmar border area.

enforcement agencies. The CITES Secretariat insists that it has no operational role, and that any operational activities arising from decisions taken under the Convention are entirely the responsibility of the signatories to the Convention.

In Thailand a new law reform passed in 2019 under the Thailand Forest Act (Section 7 of the 1941 law) listing 171 "reserved" timber species, including Siamese rosewood and Burmese rosewood, that may be legally felled and traded. The government aims to make the most of the economic value of precious woods and to encourage people to grow
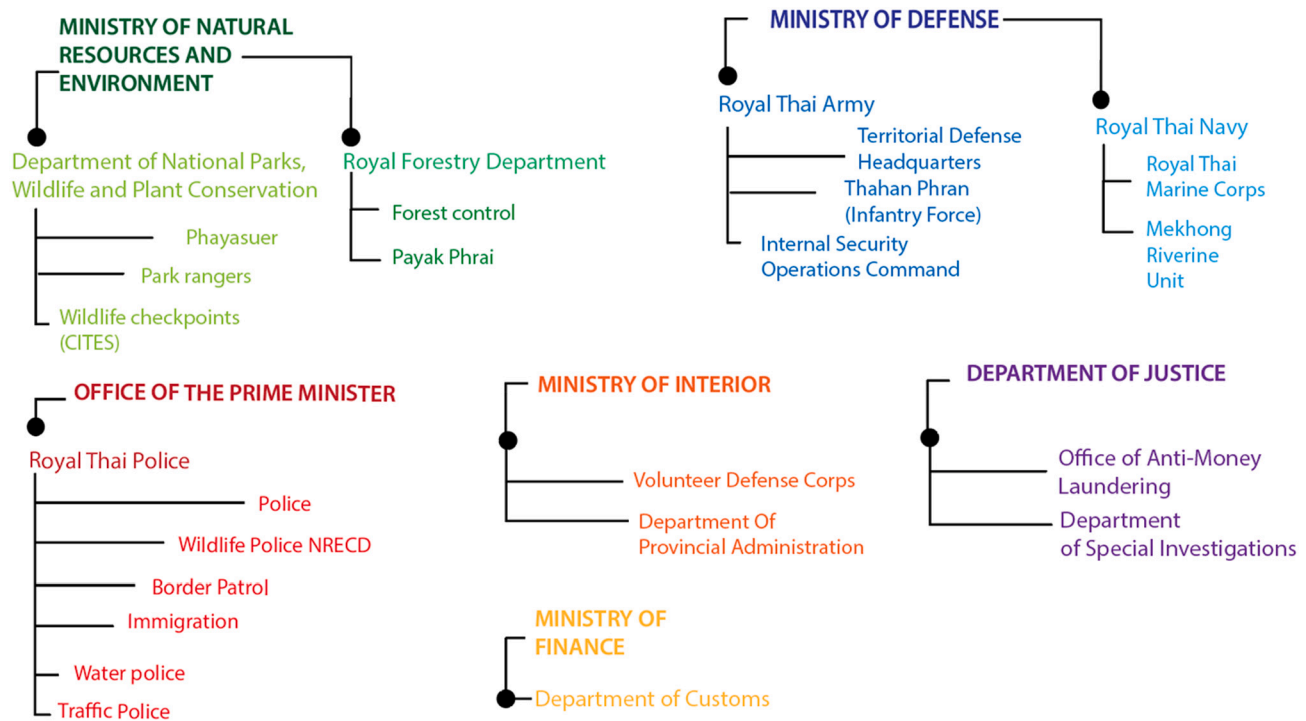
Fig. 3. The various agencies in Thailand mentioned in carrying out or partaking rosewood seizures listed under the six different ministries they report to. Based on 2187 seizure reports.

and trade timber grown on private land. Under this Act, precious trees are also recognized as tangible assets and can be used as collateral for procuring loans in a programmed called 'Tree Bank'. While part of these initiatives is to be supported, prudence is called for in its swift implementation as it may create a series of loopholes that allowed illegally sourced rosewood to enter the trade as legally obtained rosewood.

The purpose of the reformation is to generate income for farmers who may possess several of economically valuable species such as teak, Siamese rosewood and Burmese rosewood. However, given the ineffectiveness of the enforcement of existing laws leading to a continuation of the illegal trade in rosewoods, the reformation may lead to an unwanted increase in logging and trade. As seen in Madagascar, gaps in legislation and the ineffective implementation of those laws provide rosewood timber species result with unintended consequences which may bode negatively (Reeve, 2015). With the current legal infrastructure in place, law enforcement authorities still report difficulty species identification and tracking the legitimacy of wood in commercial market species, for example, in 2016 where over 100 cases of Siamese rosewood seizures reported in Thailand were due to misdeclaration (UNODC, 2016).

High-value timber species like rosewood often do not grow fast enough to compensate commercial trading volumes (Winfield et al., 2016). Rosewood and ebony species have a growth period from 80 to 300 years and sustainable extraction will therefore be near impossible (Wilmé et al., 2020). There are also unclear measures implemented to prove identification of species (Ferris, 2014; Ugochukwu et al., 2018), ownership of timber, but also the time of when it was felled, where stockpiles of timber felled prior to a logging ban may be introduced into trade later. DNA or forensic information of timber verifying its source origin is not yet available to date. In combination with Thailand's newer flexible legislation of trade, this may undermine controls implemented to protect all rosewood species and impose complexities in enforcing CITES. The lack of general census available on remaining trees, and the lack of transparency at current calls for urgent addressing to better understand trade and mechanisms and processes involved in the legal trade.

Furthermore, along with loser legal frameworks, the question should also arise with what to do with Thailand's stockpiles – with little information on stockpiles being publicly available this is something in which we have very limited insight. Wilmé et al. (2020) recently discussed management options in unresolved CITES issue of Madagascar's rosewood stockpile and call for urgency in stock management. Under Madagascar's framework to better regulate licenses for timber trade, the government moved to ban all timber trade within the country (Wilmé et al., 2020), and as a result led to a dilemma in dealing with stocks of illegally sourced timber that exacerbates the complexity in rosewood trafficking (Wilmé and Waeber, 2019). In all trade options, there is a lack of information on current volumes of legal and illegal stockpiles and presents high risks that encourage continual illegal logging and laundering (Wilmé et al., 2020). They find that all management solutions will depend on a robust foundation for any trade policy approach to be effective.

4.3. Seizure data for green criminology

Since 1990s, green criminology is a growing interdisciplinary field which calls attention to crimes related to the environment, ecological and species justice (Lynch and Stretesky, 2014). Seizure data offers a means of data analysis that moves beyond the mainstream avenues of criminology that traditionally focuses on individual offenders, and allows to explore larger trade networks to inform data gaps in green criminology (Nurse, 2017). Seizure data offer valuable insights into the specific nuances, patterns, and complexities of illegal wildlife trade networks, as has been demonstrated in other wildlife trade (Underwood et al., 2013; Nijman, 2015; D'Cruze and Macdonald, 2016; UNODC, 2016; Cheng et al., 2017; LeClerc and Savona, 2017; Yeo et al., 2017; Indraswari et al., 2020; Paudel et al., 2022).

Data from an individual seizure can reveal important aspects of criminal networks (van Uhm, 2016), for example, valuable intel on origins of logged timber, transport means, and the intended destinations give insight into spatial patterns, meanwhile, building on datasets can reveal temporal patterns and help predict future cycles and trends of

trade as well (LeClerc and Savona, 2017). Lessons can be taken from approaches made in combating and networking the trades of wild animals, such as pangolins (Ingram et al., 2019) and wild birds (Indraswari et al., 2020). Both our and Paudel et al.'s (2022) study, dealt with individual seizures from a single country (Thailand and Nepal, respectively), and a lot is to be learned from international cooperation and coordination linking seizure reports at an international level. We demonstrate that seizure data is an additional tool which can help contribute to the field of green criminology, in addition to issues such as natural resource exploitation, wildlife poaching (Rizzolo et al., 2016) and environmental sentencing (Cochran et al., 2018). The overall goal is to increase understanding in environmental crimes as illustrated from a lucrative multibillion dollar industry that impacts and threatens the security of the humans and society (White, 2013; 't Sas-Rolfes et al., 2019).

As timber crimes are generally not viewed as a harsh wildlife crime, reporting is not stigmatized compared to crimes reported on animals. However, the perception of the local domestic crime is in fact inaccurate; the findings in this study reveal a transnational nature, often backed by crime syndicates, involving illegal crossing of borders, multinational level crime. In addition, the scale of many illegal logging operations, and the number of people involved, lead to substantial collateral damage to the environment (including damage because of team spending time in the forests, damage due to extraction of wild meat, degradation of forest due to extraction methods, etc.).

Local and national news are updated daily; it therefore reflects real-time trends of trade patterns and addresses the issue of periodical delays that would traditionally be faced with reports from other NGOs (Phelps et al., 2010). We were able to test the veracity of the media reports by comparing it against another, independent, dataset of seizures from the Thai government, and found a good degree of agreement. Paudel et al. (2022) compared media reports against official seizure records for Katmandu, Nepal, and likewise found a strong positive correlation, albeit that media under-reported seizure numbers. Publicly available seizure data can therefore be used in conjunction with and as complement to official government trade data to offer a more comprehensive complete view of the trade.

Evaluation of effectiveness of measures, whether at a domestic level or for initiatives like CITES rely on reporting of information (Lopes et al., 2019). The records can be used to proactively monitor gaps in enforcement efforts. Analyses on spatial and temporal data can inform on conservation measures, increasing effectiveness of protocols which can have directed targeted allocation of resources to monitor and form law enforcement actions. Actions can help decision making at both top-down and bottom-up approaches. In the perspective of criminology, organized crime is not geographically limited, and coordinated efforts have to be made between countries along the entire supply chain (Lopes et al., 2019).

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The authors declare that they have no conflict of interest.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

References

Albrecht, H.J., 2011. International Crime, Crimes Against Humanity and Markets of Violence. Universalis Liber amicorum Cyrille Fijnaut, pp. 301–312.

Anonymous, 2016. กรมป่าไม้ เปิดเผยคดีลักลอบตัดไม้ชิงสูงกว่า 2,500 คดี โดยเฉพาะไม้พะยูงถูกลักลอบตัด สูงสุดจากเขตป่า แต่ยังไม้สามารถสกัดต้น ทางของขบวนการลักลอบตัด และค้าไม้ผิดกฎหมายได (Royal Forestry Department reveals over 2,500 cases of illegal rosewood logging in protected areas). Available at. National News Bureau of Thailand. http://nwnt.prd.go.th/centerweb/news/NewsDetail?NT01_NewsID=WNEVN5906110020003. (Accessed 15 July 2016).

Anonymous, 2017. Rosewood Case Study. UNODC, Vienna.

Arunkumar, A.N., Warrier, R.R., Kher, M.M., Teixeira da Silva, J.A., 2021. Indian rosewood (Dalbergia latifolia roxb.): biology, utilisation, and conservation practices. Trees 1–16.

Bandoh, W.K.N., Adjonou, K., Segla, K., Dumenu, W.K., Johnson, B.N., Alaba, P., Kokutse, A.D., Rabiou, H.G., Ouinsavi, C.A.I.N., Jimoh, O.S., Akinyele, A., 2022. Towards sustainable management of African rosewood in west and Central Africa: a scoping review of current research. Int. For. Rev. 24, 129–144.

Barber-Meyer, S.M., 2010. Dealing with the clandestine nature of wildlife-trade market surveys. Conserv. Biol. 24, 918–923.

Barrett, M.A., Brown, J.L., Morikawa, M.K., Labat, J.N., Yoder, A.D., 2010. CITES designation for endangered rosewood in Madagascar. Science 328, 1109–1110.

CITES, 2016. Consideration of Proposals for Amendment of Appendices I and II, CoP17 Prop. 53. Convention on International Trade in Endangered Species, Johannesburg, South Africa.

CITES, 2020. The CITES species. In: The Convention on International trade in Endangered Species of Wild Fauna and Flora (CITES). https://stag.cites.org/eng/disc/species.php.

Cao Ngoc, A., Wyatt, T., 2013. A green criminological exploration of illegal wildlife trade in Vietnam. Asian J. Criminol. 8, 129–142.

Challender, D.W.S., Harrop, S.R., Macmillan, D.C., 2015. Understanding markets to conserve trade threatened species in CITES. Biol. Conserv. 187, 249–259.

Cheng, W., Xing, S., Bonebrake, T.C., 2017. Recent pangolin seizures in China reveal priority areas for intervention. Conserv. Lett. 10, 651–789.

Cochran, J.C., Lynch, M.J., Toman, E.L., Shields, R.T., 2018. Sentencing patterns for environmental crimes: is there a "green" gap in punishment? J. Quant. Criminol. 34, 37–66.

D'Cruze, N., Macdonald, D.W., 2016. Tip of an iceberg: global trends in CITES wildlife confiscations. J. Nat. Conserv. 15, 47–63.

Dumenu, W.K., 2019. Assessing the impact of felling/export ban and CITES designation on exploitation of African rosewood (Pterocarpus erinaceus). Biol. Conserv. 236, 124–133.

Dwyer, M.B., Ingalls, M.L., Baird, I.G., 2016. The security exception: development and militarization in Laos's protected areas. Geoforum 69, 207–217.

EIA, 2014. Routes of Extinction: The Corruption and Violence Destroying Siamese Rosewood in the Mekong. Environmental Investigation Agency, London, UK.

EIA, 2016. The Hongmu Challenge: A Briefing for the 66th Meeting of the CITES Standing Committee. Environmental Investigation Agency, London, UK.

EIA, 2020. Cashing-in on Chaos: How Traffickers, Corrupt Officials, and Shipping Lines in the Gambia Have Profited From Senegal's Conflict Timber. Environmental Investigation Agency, London, UK.

Elliot, L., 2012. Fighting transnational environmental crime. J. Int. Aff. 66, 87–104.

Ferriss, S., 2014. An Analysis of Trade in Five CITES-listed Taxa. Chatham House/TRAFFIC, London UK.

Fukushima, C.S., Tricorache, P., Toomes, A., Stringham, O.C., Rivera-Téllez, E., Ripple, W.J., Peters, G., Orenstein, R.I., Morcatty, T.Q., Longhorn, S.J., Lee, C., 2021. Challenges and perspectives on tackling illegal or unsustainable wildlife trade. Biol. Conserv. 263, 109342.

Gaisberger, H., Fremout, T., So, T., Thammavong, B., Bounithiphonh, C., Hoa, T.T., Yongqi, Z., Kanchanarak, T., Changtragoon, S., Sreng, S., Ping, H., 2022. Range-wide priority setting for the conservation and restoration of Asian rosewood species accounting for multiple threats and ecogeographic diversity. Biol. Conserv. 270, 109560.

Gomez, L., Shepherd, C.R., 2018. Trade in bears in Lao PDR with observations from market surveys and seizure data. Glob. Ecol. Conserv. 15, 00415.

Hoare, A., 2015. Tackling illegal logging and the related trade, what progress and where next? Chatham House Report.

Hughes, A.C., 2021. Wildlife trade. Current Biol. 31, 1218–1224.

Innes, J., 2010. Madagascar rosewood, illegal logging and the tropical timber trade. Madag. Conserv. Dev. 5, 5–10.

Indraswari, K., Friedman, R.S., Noske, R., Shepherd, C.R., Biggs, D., Susilawati, C., Wilson, C., 2020. It's in the news: characterising Indonesia's wild bird trade network from media-reported seizure incidents. Biol. Conserv. 243, 108431.

Ingram, D.J., Cronin, D.T., Challender, D.W.S., Venditti, D.M., Gonder, M.K., 2019. Characterising trafficking and trade of pangolins in the Gulf of Guinea. Glob. Ecol. Conserv. 17, 00576.

Jiao, Y., Yeophantong, P., Lee, T.M., 2021. Strengthening international legal cooperation to combat the illegal wildlife trade between Southeast Asia and China. Front. Ecol. Evol. 9, 645427.

Kansanga, M.M., Dinko, D.H., Nyantakyi-Frimpong, H., Arku, G., Luginaah, I., 2021. Scalar politics and black markets: the political ecology of illegal rosewood logging in Ghana. Geoforum 119, 83–93.

Lynch, M.J., Stretesky, P.B., 2014. Exploring green criminology: Toward a green criminological revolution. Ashgate, Farnham.

Lynch, M., 1990s. The greening of criminology: a perspective on the 1990s. Crit. Criminol. 2, 11–12.

LeClerc, B., Savona, E.U., 2017. Crime Prevention in the 21st Century: Insightful Approaches for Crime Prevention Initiatives. Springer, Cham.

Lopes, R.J., Ferreira, J.M., Moraes-Barros, N., 2019. Bolder steps to fight global wildlife illegal trade. Conserv. Biol. 33, 7–8.

Morton, O., Scheffers, B.R., Haugaasen, T., Edwards, D.P., 2021. Impacts of wildlife trade on terrestrial biodiversity. Nat. Ecol. Evol. 5, 540–548.

Ni, Q., Yu, G., Nijman, V., Nekaris, K.A.I., Xu, H., Zhang, M., Yao, Y., Xie, M., 2022. Spatial heterogeneity and socioeconomic transformation challenge the prevention of illegal wildlife consumption in China. Biol. Conserv. 275, 109751.

Nijman, V., 2015. Pangolin seizures data reported in the Indonesian media. Traffic Bull. 27, 44–46.

Nijman, V., 2019. Wildlife trade, CITES and the protection of marine molluscs in Indonesia. Molluscan Res. 39, 195–204.

Nijman, V., Siriwat, P., Shepherd, C.R., 2022. Inaccuracies in the reporting of volume and monetary value of large-scale rosewood seizures. Forest Policy Econ. 134, 102626.

Nurse, A., 2017. Green criminology: shining a critical lens on environmental harm. Palgrave Communications 3, 1–4.

Paudel, K., Hinsley, A., Veríssimo, D., Milner-Gulland, E., 2022. Evaluating the reliability of media reports for gathering information about illegal wildlife trade seizures. PeerJ 10, 13156.

Petrossian, G.A., Pires, S.F., van Uhm, D.P., 2016. An overview of seized illegal wildlife entering the United States. Glob. Crime 2, 181–201.

Phelps, J., Webb, E.L., Bickford, D., Nijman, V., Sodhi, N.S., 2010. Boosting CITES. Science 330, 1752–1753.

Pires, S.F., 2012. The illegal parrot trade: a literature review. Glob. Crime 13 (3), 176–190.

R Core Team, 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Randriamalala, H., Liu, Z., 2010. Rosewood of Madagascar: between democracy and conservation. Madag. Conserv. Dev. 5, 11–22.

Reeve, R., 2002. Policing International Trade in Endangered Species: The CITES Treaty and Compliance. Earthscan, London, UK.

Reeve, R., 2015. The role of CITES in the governance of transnational timber trade. In: Occasional Paper 130. CIFOR, Bogor, Indonesia.

Rivalan, P., Delmas, V., Angulo, E., Bull, L.S., Hall, R.J., Courchamp, F., Rosser, A.M., Leader-Williams, N., 2007. Can bans stimulate wildlife trade? Nature 31, 529–530.

Rizzolo, J.B., Gore, M.L., Ratsimbazafy, J.H., Rajaonson, A., 2016. Cultural influences on attitudes about the causes and consequences of wildlife poaching. Crime, Law Soc. Chang. 67, 415–437.

Scheffers, B.R., Oliveira, B.F., Lamb, I., Edwards, D.P., 2019. Global wildlife trade across the tree of life. Science 366, 71–76.

Schuurman, D., Lowry, P., 2009. The Madagascar rosewood massacre. Madag. Conserv. Dev. 4, 98–103.

Singh, S., 2014. Borderland practices and narratives: illegal cross-border logging in northeastern Cambodia. Ethnography 15, 135–159.

Santos, A., Satchabut, T., Vigo Trauco, G., 2001. Do wildlife trade bans enhance or undermine conservation efforts? Appl. Biodivers. Perspect. Ser. 1, 1–15.

Siriwat, P., Nijman, V., 2018. Using online media-sourced seizure data to assess the illegal wildlife trade in Siamese rosewood. Environ. Conserv. 45, 419–424.

't Sas-Rolfes, M., Challender, D.W.S., Hinsley, A., Veríssimo, D., Milner-Gulland, E.J., 2019. Illegal wildlife trade: scale, processes, and governance. Annu. Rev. Env. Resour. 44, 201–228.

Treanor, N.B., 2015. China's Hongmu Consumption Boom: Analysis of the Chinese Rosewood Trade and Links to Illegal Activity in Tropical Forested Countries. Forest Trends, Washington, DC, USA.

UNODC, 2016. World Wildlife Crime Report. United Nations Office on Drugs and Crime, Vienna, Austria.

UNODC, 2020. World Wildlife Crime Report – Trafficking in Protected Species. United Nations Office on Drugs and Crime, Vienna, Austria.

UNODC, 2013. Transnational Organized Crime in East Asia and the Pacific A Threat Assessment. United Nations Office on Drugs and Crime, Vienna, Austria.

Treanor, N.B., 2022. CITES takes unprecedented steps to stop the illegal African rosewood trade. Forest Trends, Washington.

Ugochukwu, A.I., Hobbs, J.E., Phillips, P.W., Kerr, W.A., 2018. Technological solutions to authenticity issues in international trade: the case of CITES listed endangered species. Ecol. Econ. 146, 730–739.

Underwood, F.M., Burn, R.W., Milliken, T., 2013. Dissecting the illegal ivory trade: an analysis of ivory seizures data. PLoS One 8, 76539.

van Uhm, D.P., 2016. TheIllegal Wildlife Trade. Inside the World of Poachers, Smugglers and Traders. Springer International Publishing, Cham, Switzerland.

Vardeman, E., Runk, J.V., 2020. Panama's illegal rosewood logging boom from Dalbergia retusa. Glob. Ecol. Conserv. 23, 01098.

Waeber, P.O., Schuurman, D., Ramamonjisoa, B., Langrand, M., Barber, C.V., Inness, J.L., Lowry, P.P., Wilmé, L., 2019. Uplisting of malagasy precious woods critical for their survival. Biol. Conserv. 235, 89–92.

Winfield, K., Scott, M., Grayson, C., 2016. Global status of *Dalbergia* and *Pterocarpus* rosewood producing species in trade. CITES, Geneva.

Wilmé, L., Waeber, P.O., 2019. Brand Madagascar's rosewood and ebony as endangered. Nature 565–567.

Wilmé, L., Innes, J.L., Schuurman, D., Ramamonjisoa, B., Langrand, M., Barber, C.V., Butler, R.A., Wittemyer, G., Waeber, P.O., 2020. The elephant in the room: Madagascar's rosewood stocks and stockpiles. Conserv. Letters 13 (4), 12714.

Warchol, G.L., 2004. The transnational illegal wildlife trade. Justice Prof. 17 (1), 57–73.

Wyatt, T., 2009. Exploring the organization of Russia Far East's illegal wildlife trade: two case studies of the illegal fur and illegal falcon trades. Glob. Crime 10 (1–2), 144–154.

Wyatt, T., 2013. The security implications of the illegal wildlife trade. J. Social Criminol. 8, 130–158.

White, R., 2013. The Conceptual Contours of Green Criminology. In: Part of the Critical Criminological Perspectives Book Series (CCRP).

Wyler, L.S., Sheikh, P.A., 2013. InternationalIllegal Trade in Wildlife: Threats and US Policy (Congressional Research Service). Available at. www.fas.org/sgp/crs/misc/RL34395.pdf. (Accessed 1 February 2020).

Yeo, L.M., McCrea, R.S., Roberts, D.L., 2017. A novel application of mark-recapture to examine behaviour associated with the online trade in elephant ivory. PeerJ 5, e3408.

Zhu, A., 2017. Rosewood occidentalism and orientalism in Madagascar. Geoforum 86, 1–12.

Zhu, A.L., 2022. Rosewood: Endangered Species Conservation and the Rise of Global China. Harvard University Press, Harvard.

Zimmerman, M., 2003. The black market for wildlife: combating transnational organized crime in the illegal wildlife trade. Vand. J. Transnat'l. L. 36, 1672–1673.