The sustainability of the elephant ivory trade in Thailand: demand, supply and controls

Thesis submitted by

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Statement of contributions to individual chapters

Initials: AC = Apinya Chaitae; HM = Helene Marsh; IG = Iain Gorgon; JA = Jane Addison; RR= Ronnarit Rittiron; SP = Suttahatai Pochanagone; NS = Nattakan Suttanon; Rhondda Jones: RJ

Chapter	Statement of Contribution
Chapter 1 Introduction	AC wrote the chapter with feedback from supervisors: HM, IG and JA.
Chapter 2 Ivory trade controls with respect to CITES obligations	AC conceived and wrote the chapter with feedback from supervisors: HM, IG and JA.
Chapter 3 Legal awareness and compliance of relevant ivory trade actors	Study design was conceived by AC. AC collected data, transcribed all audio-recorded interviews, and conducted analyses. AC drafted the chapter. HM, IG and JA helped with data interpretation and manuscript edits. JA assisted in designing the interview & questionnaire questions, data collection strategies, and social study analysis. RJ provided statistical advice.
Chapter 4 Developing a forensic technique to differentiate ivory provenance	Study was conceptualized by AC, RR, IG. AC, RR, IG, HM, JA, and SP designed the study. AC, SP, NS collected data. AC analysed data with help from RR, SP. AC wrote the chapter. RR, IG, HM, JA, SP and NS helped with data interpretation and manuscript edits.
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Chapter 7 Synthesis and discussion	AC wrote the chapter with feedback from supervisors: HM, IG and JA.

Abstract

The ivory trade is of global interest due to its potential impacts on elephant conservation. Thailand permits the domestic trade of ivory from registered Thai domesticated elephants. The legal status of privately owned, captive elephants differs from that of wild individuals, with consequences for the lawful use of ivory from captive animals. Tusks from privately-owned elephants continue to be trimmed for reasons of human safety and elephant welfare, providing an ongoing source of ivory from live animals. In addition, whole tusks are harvested from Asian elephants that die naturally. Nonetheless, the Thai domestic ivory trade is controversial because of the perception that it is unsustainable and inadequately controlled and may mask an illegal market for ivory from both African and other Asian elephants.

A sustainable domestic ivory market in Thailand has the potential to benefit the local economy, the individual livelihoods of actors in the domestic ivory supply chain and the conservation of Asian elephants. My research aimed to inform the evidence base for a sustainable ivory market in Thailand using comprehensive and novel approaches involving both natural and social science methods. To achieve the aim, I addressed two main objectives: 1) To investigate how control mechanisms relevant to the domestic ivory trade in Thailand could be strengthened; and 2) To understand the market interactions related to the legal domestic ivory trade in Thailand. These objectives were expanded into five sub-objectives, each addressed in a data chapter in this thesis.

For the ivory control mechanism (Objective 1), I reviewed Thai legislation related to the control of domestic ivory trade and compliance with the CITES convention. There are eight laws relevant to the control of ivory depending on the legal status of the source elephants. The relevant legislation, reformed in 2015, meets CITES obligations and enables the control of both the international and domestic ivory trade. However, this complex legal framework imposes a significant compliance burden on relevant users due to its complexity and high transaction costs. Elephant owners, ivory traders and ivory consumers are aware of these laws, particularly about the illegality of ivory from African and wild Asian elephants, as well as the restrictions around the domestic trade and the export and import of ivory. However, I found that the accuracy and scope of knowledge varied among groups of actors in the ivory supply chain. Some elephant owners were

confused about the administrative procedures resulting from multiple laws, although their overall perception of the system was generally positive. Ivory consumers were generally unclear about the legal status of domesticated elephant ivory. Ivory traders are the actors holding the greatest knowledge of the legal situation and play a key role in educating the other two groups of actors (i.e., elephant owners and ivory consumers) via their trading activities.

Effective control is essential to maintaining a legal market for ivory. To support the monitoring by field officers, I investigated the capacity of non-destructive Near Infrared (NIR) spectroscopy, combined with Partial Least Squares Discriminant Analysis (PLS-DA), to discriminate between ivory from African, wild Asian and domesticated Asian elephants. The results confirmed the potential of NIRS to differentiate elephant ivory provenance at both the interspecies (African and Asian elephant ivory), and within species (wild and domesticated Asian elephant ivory) levels. Further development of handheld NIRS devices for enforcement has the potential to support officers in identifying elephant ivory and prevent the laundering of illegal ivory, an important pre-requisite for a sustainable legal market.

In addressing Objective 2, I found that the legal, domestic supply chain in Thailand comprises five key actor groups: elephant owners, intermediaries, manufacturers, retailers, and ivory consumers. Ivory supply is influenced by several factors. Tusks cutting is a non-lethal, long-established and necessary practice in domestic elephant keeping, whilst selling tusks is increasing due to the rising costs of Thai elephant owners, and market demand. The legal ivory trade provides extra income for Thai elephant owners, but market access is not equal among them. The limited legal knowledge of elephant owners narrows their market access. Elephant keeping networks facilitate the flow of raw ivory to buyers. Each year, Thai domesticated elephants supply, at least, ~375 kg of legal raw ivory. About 65% of this is possessed privately; the remaining 35% supplies the commercial manufacturing of ivory products.

The ivory purchasing decisions of shop customers are strongly influenced by factors related to their trust in, and the credentials of, traders. This is presumably because of the customers' concerns over the authenticity and legality of the ivory products that they wish to purchase. The attitudes of customers could be further leveraged to facilitate and increase legal compliance amongst consumers. Attitudes to elephant ivory consumption in Thailand

are linked to the extraordinary cultural and religious value of Thai elephants, and the legality of domesticated elephant ivory. Most of the transactions of annual raw ivory supply are conducted privately rather than from ivory shops. Further in-depth study of the motivations of all ivory consumers would benefit management

My findings establish the key dimensions of the Thai ivory trade and have the potential to inform management initiatives that strengthen the Thai government' efforts towards sustainability. Enforcement and trade controls would benefit from the potential capacity of Near Infrared Spectroscopy to differentiate between the ivory from domesticated Asian elephants and illegal ivory (i.e., wild Asian and African elephant ivory). Simplified laws would facilitate legal compliance, especially if these laws took advantage of positive perceptions towards laws particularly among elephant owners. The legal awareness of elephant owners and ivory consumers needs to be raised by harnessing the education potential of ivory traders. The legal ivory trade is based on trust-orientated transactions. I identified the importance of ivory traders, as being in the central and trusted position in the supply chain, for planning awareness raising, as well as promoting legal compliance.

Behavior change interventions should be based on connections between ivory and elephants in Thailand. Interventions should focus on customers' concerns about the authenticity and legality of ivory products. Mechanisms, such as a central market that facilitates a more equitable trade of raw ivory, would maintain the value of legal Thai ivory and support ivory trade regulation. Supply knowledge, both from supply chain study and the annual local ivory volume, provides valuable information for management and enforcement.

My synthesized findings, which represent a significant, original contribution to the knowledge of the Thai ivory trade, have the potential to inform the management of the legal Thai ivory market. These reforms, together with the existing efforts of Thai government to regulate the domestic ivory trade, would benefit by actively involving Thai people in their implementation and enhance elephant conservation.

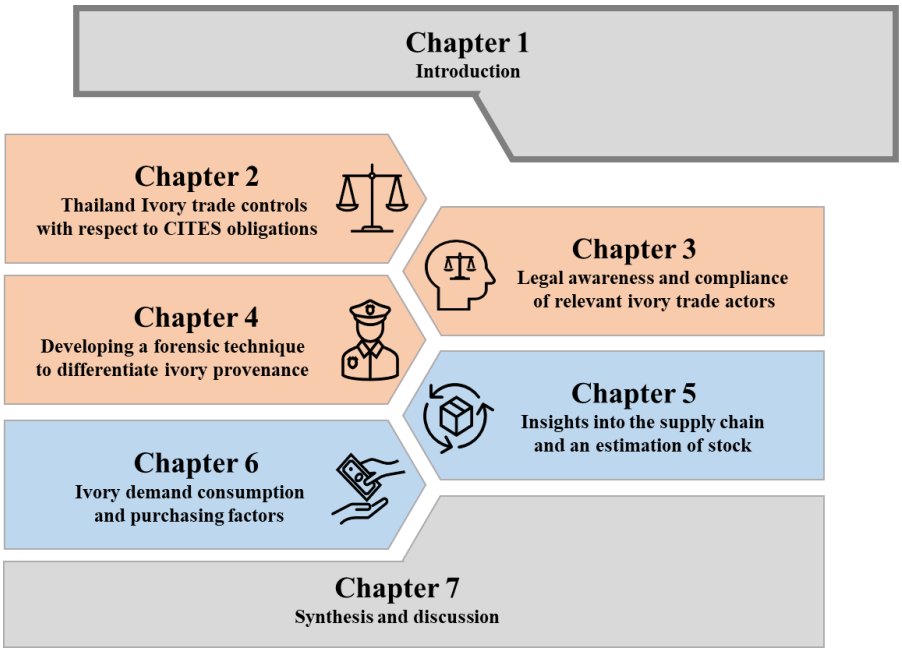
Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

This introductory chapter reviews the relevant literature on the international wildlife trade, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the conservation status of elephants and the elephants ivory trade, and outlines the rationale, objectives and structure of this thesis.



1.1 Wildlife trade

Human activities, both direct and indirect, have devastated many species of wild animals and plants *(WWF, 2018).* Habitat loss and fragmentation are major causes of local extinction (Ferraz et al., 2007; Rogan & Lacher, 2018; WWF, 2018). Forest fragmentation, especially caused by deforestation, divides contiguous forest areas into small fragments (Fitzsimmons, 2003; Laurance, 2000). The detrimental effects to wild species living in fragmented forest include loss of suitable habitat and connectivity (De Angelo et al., 2011; Hennings, 2010; Olsoy et al., 2016), decreased reproductive success (Hinam & Clair, 2008), high hunting exposure (Canale et al., 2012), diminished persistence and abundance (Michalski & Peres, 2017) and high forest fire incursion (Alencar et al., 2004). The introduction of invasive species can also have devastating impacts on wildlife; for example, the extinction of Guam native birds by exotic Brown Tree Snake (*Boiga irregularis*) (Rodda & Savidge, 2007). Feeding and trampling by feral hard-hoofed mammals, such as goats, have changed plant communities and ecosystem structures (Chynoweth et al., 2013).

The trade in wildlife is another pressing threat causing wildlife population declines and even species' extirpation (Symes et al., 2017). The wildlife trade has both illegal and legal elements. Unsustainable levels of trade directly impact the survival of traded species (Broad et al., 2003). For example, the growing demand for ivory has resulted in the loss of about half of the African elephant (*Loxodonta* spp.) population since 1981 (Thouless et al., 2016); for instance, Tanzanian elephant numbers declined by 60%, from ~109,000 in 2009 to ~43,330 in 2014 (Mathiesen, 2015). Likewise, around 50% of the elephant population in Mozambique was poached within a five-year period (2009-2014) (Mathiesen, 2015). Even today, elephant populations in Central and West Africa face illegal hunting for their ivory (CITES, 2017).

The white (*Ceratotherium simum*) and black (*Diceros bicornis*) rhinoceros, are also poached to supply the medicinal and trophy trade in Asia (Emslie et al., 2019). Poaching of both species of rhinoceros is estimated to have increased since 2006 and reached a peak in 2015 with about four animals a day poached across their range states. Poaching levels are declining although still at high levels with *c.* three rhino/day poached in 2017 (Emslie et al., 2019). The remaining populations of both rhino species combined was estimated to be ~23,500 animals in 2017 (Emslie et al., 2019). The white rhinoceros is now listed on the

IUCN Red List of Threatened Species as "Near Threatened", whilst the black rhinoceros is listed in the "Critically Endangered" category (Emslie, 2020a, 2020b).

The pangolins (Manidae spp.), or scaly anteaters, is another group affected by the high demand for medicinal products. Pangolins are considered to be the most heavily trafficked wild mammal in the world (Challender et al., 2014). Pangolin scales are used for a variety of purposes in traditional medicines, whilst their meat is also widely consumed in both their African and Asian range states (Challender & Waterman, 2017). The illegal trade of all eight pangolin species, between 1999 and 2017, is estimated at ~192,500 individuals (Challender & Waterman, 2017). China was the key destination for large shipments of scales and whole animals that were seized during the period 2010-2015, while large shipments of body parts (e.g., skins, leather products, medicines) were mainly destined for the USA (Heinrich et al., 2017). The increasing demand for pangolins, in particular the international demand, has led to unsustainable harvesting, depleting populations in most of their range states. For example, the population of the Chinese pangolin has declined in excess of 90% in China and its immediate surrounds (Wu, 2004). The IUCN categorises three pangolin species as Critically Endangered, three as Endangered and two as Vulnerable (IUCN Redlist, 2022).

A sustainable, legal trade in wild animals and plants can benefit long-term economies at local, national and international levels (Broad et al., 2003). In 2005, the estimated global value of the legal wildlife trade was A$390 billion (Engler & Parry-Jones, 2007). The annual value of the legal wildlife trade in the European Union (EU) accounts for 38% of the global trade, worth A$138 billion, $149 million of which comes from the reptile skin trade (Duffy, 2016). Australia supplies about 60% of the global trade in crocodile products, two-thirds of which comes from the Northern Territory (Simmons, 2017). In 2012, the EU and the USA were the key markets for premium crocodile skin products (Ernst & Young, 2017). The crocodile farming business in the Northern Territory generated about $106 million for the Territory's economy in the financial year 2014/15. In addition to skin sales, this economic output was generated through a variety of farm-related activities e.g., construction, operation, tourism, veterinary service, as well as employment for the surrounding communities, including remote Indigenous communities. (Ernst & Young, 2017).

Despite concerns around the unsustainability of the illegal trade of rhino horn, legalization of the rhino horn trade could generate economic benefits both for local communities and rhino protection (Biggs et al., 2013; Di Minin et al., 2015; Rubino & Pienaar, 2020). Under an optimal scenario of maintaining the rhinoceros population above its current size, a legal trade in rhinoceros horn has been estimated to potentially generate annual profits of $717,000,000 to South Africa, almost five times greater than the $147,000,000/year costs of enforcement without trade legalization (Di Minin et al., 2015). The domestic rhino horn trade in South Africa is expected to provide an economic incentive to keep rhinos on private ranches and fund the cost of protection and management (Rubino & Pienaar, 2020). Accessible legal stocks can reduce the price of illegal horns resulting in a decrease in poaching incentive (Biggs et al., 2013). Non-lethal harvested horns from wild or farmed sources offer renewable resources to supply consumption (Taylor et al., 2017).

Trade in the wool from the vicuna (*Vicugna vicugna*), a wild South American camelid, which lives in the high alpine areas of the Andes, is a well-recognized example of sustainable legal wildlife trade that benefits species and habitat conservation as well as the livelihoods of local communities (Gordon, 2008). The vicuna populations of Argentina, Bolivia, Chile and Peru, are listed in CITES Appendix-II, which allows international commercial trade (CITES, 2022a). These countries have different approaches to harvesting the fine wool from vicuna; in Peru, some populations are enclosed within ranches; in Chile there are attempts to domesticate vicuna; whilst in Argentina and Bolivia wild vicuna are corralled, shorn and released (Gordon, 2008). Peru, the largest exporter, generated USD 2.5 million in 2017 from vicuna wool and its products (Kasterine & Lichtenstein, 2018). The wool is largely exported to Italy for manufacturing premium cloth and garments that are re-exported to end-user markets in several countries e.g., China, the US, Switzerland, Japan (Kasterine & Lichtenstein, 2018). Trade in this species is conducted in accordance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

1.2 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES, which entered into force in 1975, is an international Agreement between 184 signatory states parties, that aims to govern the international trade in wild animals and plants to ensure that the trade does not threaten the survival of traded species (CITES, 2018). Thailand ratified the CITES convention in 1983 (CITES, 2022b). CITES regulates through a permit system for the species of wild animals and plants that are listed in the Agreement's appendices; permit(s) or certificate(s) are required for international trade of CITES-listed species (CITES, 2019). Import and export permissions are needed for species in Appendix I, while an export document such as permit or certificate is required for species under Appendix II and III.

The species protected under CITES are categorized into Appendices I, II, and III, reflecting the level of protection required (from high to low respectively). CITES Appendix I includes species threatened with extinction; these species are generally prohibited from the international trade for commercial purposes. International commercial trade of Appendix II and III species and their products is allowed, with restrictions. The present CITES Appendices include over 35,000 animal and plant species, a diverse group, traded in either their live and dead forms, or as parts and products.

Both African and Asian elephants are under the protection of this international treaty. CITES classifies the African savanna elephant (*L. africana*) and African forest elephant (*L. cyclotis*) as a single species i.e., African elephant (*Loxodonta africana*) (CITES, 2022a; UNEP-WCMC (Comps.), 2019). The African elephant populations are largely in Appendix I of CITES, except for populations in four countries: South Africa, Botswana, Namibia and Zimbabwe, which are listed on Appendix II (CITES, 2022a). Elephant specimens from Appendix II populations can be traded under conditional provisions, e.g., authorized one-off sales for raw ivory, a trophy-hunting quota and traditional products. All Asian elephants, including both wild and domesticated individuals, are listed as CITES Appendix I (CITES, 2022a; UNEP-WCMC (Comps.), 2019).

1.3 Conservation status of elephants

The African savannah elephant is categorized as Endangered, while the African forest elephant is listed as Critically Endangered on the IUCN Red List of Threatened Species (Gobush, Edwards, Balfour, et al., 2021; Gobush, Edwards, Maisels, et al., 2021). According to the 2016 status report for the African elephant (Thouless et al., 2016), the current population of African elephants is estimated to be between 510,000 and 570,000 individuals across 37 African countries. Most of the population (42%), lives in the Southern Africa region, which includes Botswana, Mozambique, South Africa, Zambia. Eastern Africa (e.g., Ethiopia, Kenya, Tanzania, Uganda,) supports 28% of the population, followed by Central Africa e.g., Cameroon, Congo, Democratic Republic of Congo, Gabon (25%), and West Africa e.g., Benin, Côte d'Ivoire, Mali, Nigeria (5%). The population continues to experience threats causing decline. Illegal poaching for ivory is considered a major threat to the survival of the African elephant, while habitat loss and human conflict are increasing over the continental range (Thouless et al., 2016).

IUCN considers the Asian elephant to be Endangered and number between 45,000 and 53,000 individuals (*Asian elephant range states meeting 2017 final report*, 2017; Sukumar, 2006; Williams et al., 2020). Asian elephants live in 13 range state countries in Asia i.e., India, Nepal, Bhutan, Bangladesh, Sri Lanka, Myanmar, China, Vietnam, Lao PDR, Cambodia, Thailand, Malaysia, and Indonesia. The main threats to their survival include human-elephant conflict and habitat loss/fragmentation and challenges in managing captive populations, while the illegal trade in elephant parts (e.g., ivory, skin) and live elephants are reducing their populations in some countries (*Asian elephant range states meeting 2017 final report*, 2017; Williams et al., 2020). Captive or domesticated populations of Asian elephants account for around one fourth of the total. Myanmar has the highest number of captive elephants around 5,000 individuals, Thailand and India have similar numbers of captive elephant, each 3500-4000 individuals (*Asian elephant range states meeting 2017 final report*, 2017).

1.4 Ivory trade perceptions

1.4.1 Legal trade of ivory under CITES

The term “ivory” is applied to mammalian teeth and tusks (large modified teeth projecting beyond the lips) that are large enough for carving and manufacturing into products (Espinoza & Mann, 1999). Ivory can be obtained from many species of large living mammals, e.g., elephants, hippopotamus, dugongs, whales, and the extinct mammoth (Espinoza & Mann, 1999). Ivory largely consists of the calcium-containing component and collagenous proteins, which provide material suitable for carving into a variety of products (Espinoza & Mann, 1999; *Identifying Different Types of Ivory*, n.d.). In this research context, the term ‘ivory’ is limited to elephant tusks.

CITES has allowed two one-off sales of Appendix II listed African ivory with a single shipment per destination. The first ivory shipment of 50 tons was sold to Japan in 1999; the second sale of around 108 tons was bought by China and Japan in 2009 (CITES, 2008; Japan's Ministry of the Environment, 2018). CITES authorized China and Japan as importing countries for these legal sales for domestic consumption (CITES, 2008). Resolution Conf. 10.10 (Rev. CoP18): Trade in elephant specimens (CITES Res.Conf. 10.10 (Rev. CoP18), 2019) stipulates the process required for trade in ivory at both international and domestic levels, e.g., trade in hunting trophies, trade in raw ivory for commercial purposes, ivory marking and provides guidance as to how this process should be implemented.

Ivory from elephants is domestically tradable in some countries. Markets vary in scale and regulation (CITES SC74 Doc. 39, 2022; TRAFFIC, 2004). Although the legal domestic trade has been prohibited in some non-range state countries, exemptions can be provided in certain circumstances. For instance, exemptions have been given for some small products, antiques, items with high artistic or cultural values, or those acquired before the dates of the relevant CITES provisions applied to ivory, in the United States, the United Kingdom (UK), and European Union (EU) countries (CITES SC74 Doc. 39, 2022; European Union, 2017; TRAFFIC, 2004; U.S. Fish and Wildlife Service, 2016; UK's Department for Environment, 2018). In Japan, commercial trade in ivory is allowed for: 1) pieces obtained before the ivory ban periods; 2) pre-convention ivory; and 3) stocks from the one-off sales of African ivory (Japan's Ministry of the Environment, 2018). In African elephant range

states, South Africa and Zimbabwe permit the trade of ivory from local stocks (CITES SC74 Doc. 39, 2022; Nkoke et al., 2017; TRAFFIC, 2004). Likewise, Thailand allows the use of, and trade in, the ivory of privately-owned local Asian elephants (Elephant Ivory Act B.E. 2558, 2015).

1.4.2 Global tension of ivory trade

The ivory trade is an example of the tension between international and national attempts to conserve species important in the wildlife trade. Elephant ivory is a long-standing and controversial agenda item in the CITES forum because member states have different values and needs, arguing either for a ban on, or for the legalization of, the ivory trade. Prior to African elephants being transferred to CITES Appendix I, southern African nations unilaterally argued against a ban on the commercial trade of African ivory. Their rationale was that they already employed practices for managing overabundant elephant populations and that these practices provided both ecological and economic benefits (Stiles, 2004). Elephants from countries with healthy populations were later transferred to Appendix II to facilitate sustainable conservation practices (CITES, 1997, 2000).

However, the legalization of some ivory trade has raised concerns about demand stimulated by the legal trade, complication of enforcement efforts, and the link to poaching and the illegal ivory trade. Legal trade can provide a cover for trade in illegal ivory (Mundy, 2014; U.S. Fish and Wildlife Service, 2016). For example, two New York City jewellers, selling legally-claimed ivory, were charged with illegal ivory trade in 2012 (U.S. Fish and Wildlife Service, 2016) and fake antique ivory made from new ivory in Portugal, and age-suspicious ivory items were claimed as antiques in Belgium (Mundy, 2014). The leaking of ivory products from legal domestic markets to other countries, via both offline and online traders, is also a problem (Kitade & Nishino, 2018).

This situation has led to calls for the total closure of the legal ivory trade (Aryal et al., 2018; CITES CoP17 Doc. 57.2, 2016; Dasgupta, 2016; WWF, 2022). The responses of various member countries has varied. For example, CITES parties that have no access to locally supplied ivory implemented ban of commercial domestic trade of ivory such as USA in 2016 followed by China in 2018, while the ban in Hongkong, Israel, Singapore and UK came into force during 2021 - 2022 (CITES SC74 Doc. 39, 2022; Singapore's National Parks Board, 2021; U.S. Fish and Wildlife Service, 2016; UK's Department for

Environment, 2019). The EU and its Member States have been in the process of finalizing restrictive measures for ivory trade within the EU, while New Zealand is considering the need for further restrictions regarding the small-scale domestic ivory market (CITES SC74 Doc. 39, 2022).

The 2016 IUCN conference accepted the resolution calling for governments to close their domestic markets for commercial trade in raw or worked elephant ivory (IUCN, 2016). Most member countries voted for a non-legally binding motion to close the domestic ivory trade, whereas Japan, Namibia and South Africa, all countries with regulated domestic markets, argued for continued regulation (Dasgupta, 2016). The United Nations General Assembly adopted a resolution to reinforce the need to secure legal domestic markets, and implement Resolution of the Conference of the Parties 10.10 of CITES to close legal domestic ivory markets, as a matter of urgency, if these markets contribute to poaching or illegal trade (UNGA A/71/L.88, 2017). Countries with active domestic ivory markets, including Thailand, are still being pressured to close them (Kent, 2019; WWF-Thailand, 2016).

1.4.3 Thailand domestic ivory trade

Ivory use and trade has existed for centuries in Thailand (Stiles, 2003; Thailand's Fine Arts Department, 2013). Ivory obtained from domesticated elephants is legally tradable. Prior to 2015, lack of comprehensive legislation in regulating domestic trade contributed to illegal trade of African elephant ivory both at domestic and international levels (CITES CoP16 Doc. 53.2.2 (Rev. 1), 2013). Concern about this illegal trade led to the reform of related laws to address the illegal ivory trade in Thailand during 2014 - 2015 (CITES SC66 Doc. 29 Annex 8, 2015). As a CITES member country with a domestic ivory market, Thailand is required to comply with the Resolution Conf. 10.10 (Rev. CoP18) about control of domestic ivory trade. Failure to follow this recommendation can result in trade sanction on CITES-listed species. Since introducing the new legal framework, there is no full assessment, if this enables compliance with this CITES resolution.

The control of the ivory trade in Thailand is based on the legal protections provided to elephant types with three different legal status: African and wild Asian elephants are under protection of the Wild Animal Reservation and Protection Act B.E. 2562 (2019), while domesticated Asian elephants are privately-owned and under control of the Draught Animals Act B.E. 2482 (1939). Distinguishing ivory types for a prosecution under the appropriate law

is a challenging task for enforcement. A simple and non-destructive identification tool would be preferable for enforcement officers and in-field monitoring (S. Kong-Ngoen, pers. comm, 2017). However, such a technique for differentiating domesticated Asian elephant ivory from wild Asian elephant sources had not been developed prior to my research.

Destructive identification techniques e.g., DNA analysis, spectroscopy techniques, isotopes, are well recognized as capable of differentiating sources of elephant ivory (Buddhachat et al., 2016; Edwards et al., 2006; Shimoyama et al., 2004; Shimoyama et al., 2003; Singh et al., 2006; Wasser et al., 2004; Ziegler et al., 2016). Ivory identification is mainly dependent on environmental and diet variations between different groups of elephants (Prozesky et al., 1995; Raubenheimer et al., 1998; Singh et al., 2006). There is a difference in the food regimes between domesticated elephant populations in Thailand and wild populations. A low diversity of cultivated plants and agricultural produce comprises the main diet of domesticated elephants todays (Godfrey & Kongmuang, 2009), whereas wild elephants eat a much wider variety of plants. There is a possibility that there is a difference in the chemical composition of ivory resulting from this dietary difference. However, before I started my thesis research, none of identification techniques had been used to detect differences between domesticated and wild populations of Asian elephants. A technique that can be practically use in fields to distinguish different sources of elephant ivory could improve the efficiency of Thai ivory trade controls, especially the laundering of illegal ivory.

The Thai ivory market is legally supplied only by ivory from Thai domesticated elephants. Elephant tusks grow throughout an animal's life (Sukumar, 2003) and there is thus the potential to provide a renewable resource to supply the domestic ivory trade. However, little is known about the potential ivory production of privately-owned elephants. Thai domesticated elephants were estimated to produce c. 300 - 400 kg of ivory annually (Stiles, 2009), providing an additional income for elephant owners (Chomdee et al., 2013). This trade also supports local craftsmen and maintains the traditional knowledge of ivory carving (Stiles, 2003). Previous estimates of the ivory supply are questioned by international organizations (Environmental Investigation Agency, 2018). There is a lack of comprehensive supply knowledge of the Thai ivory trade, e.g., supply chain and relevance factors.

The ivory trade in Thailand aims to satisfy domestic consumption, which is generally associated with belief in the spiritual benefits of ivory e.g., protection (USAID Wildlife

Asia, 2018). A wide range of jewellery items are the main products found in ivory shops (Krishnasamy et al., 2016). The Elephant Ivory Act 2015 regulates commercial trade via authorized ivory shops (Chaitae, Gordon, et al., 2022; Elephant Ivory Act B.E. 2558, 2015). Consumption knowledge should be obtained specifically from target groups, rather than a broader audience (Greenfield & Veríssimo, 2018). Knowledge of ivory shop customers, including factors influencing ivory consumption, could provide insights into present ivory demand, the risks of an illegal trade, as well as enabling government to customise behavioural intervention policy toward target audiences.

1.5 Thesis objectives and structure

1.5.1 Objectives

The domestic ivory trade in Thailand is an important part of the livelihood of the Thai people involved. However, a domestic trade must also minimise effects on the survival of domestic and wild elephant populations. The aim of this research **is to inform the evidence base for a sustainable ivory market in Thailand**, I address this aim via the two primary objectives, detailed below:

Objective 1: To investigate how the control mechanisms relevant to the domestic ivory trade in Thailand could be strengthened.
I have addressed this objective using three approaches:

1.1 Review current Thai legislative mechanisms for regulating ivory trade to comply with CITES obligations
1.2 Assess the legal understanding of ivory trade actors in related regulations
1.3 Explore a non-destructive ivory identification technique to support enforcement

Objective 2: To understand the market interactions related to the legal domestic ivory trade in Thailand.
This objective has been addressed in two ways:

2.1 Study domestic, legal ivory supply chain, and factors influencing ivory supply for manufacturing
2.2 Explore ivory shop consumers' consumption behaviors and attitudes

In addition, I have synthesized my findings to provide recommendations for strengthening the controls on the Thai ivory market.

1.5.2 Structure

This thesis is divided into two major sections: control mechanisms (3 chapters); and market interactions (2 chapters) reflecting the main objectives above, together with an introduction and final discussion. Its schematic structure is presented in *Figure 1.1* and outlined below.

Chapter 1: Introduction (this chapter) outlines the rationale for the research and reviews the relevant literature.

Section 1: Control mechanisms (chapters 2 – 4)

Chapter 2: Ivory trade controls with respect to CITES obligations provides the contextual background about the development and structure of a legal framework governing elephants and their ivory in Thailand and links to the Thai government's commitment to the Convention for International Trade in Endangered Species of Wild Fauna and Flora (CITES), as a signatory state (**objective 1.1)**. This chapter has been published in *Oryx* (Chaitae, Gordon, et al., 2022).

Chapter 3: Legal awareness and compliance of relevant ivory trade actors assesses how key groups of actors (elephant owners, ivory traders, and ivory consumers) understand regulations in relevant to their ivory activities. The chapter also documents the results using the Unmatched Count Technique (UCT) for assessing legal compliance for a group of ivory consumers. The manuscript associated with this chapter is currently under revision and will be submitted for publication in a peer reviewed journal. This chapter addresses **objective 1.2**.

Chapter 4: Developing a forensic technique to differentiate ivory provenance applies the Near Infrared Spectroscopy (NIRS) technique for differentiating ivory sourced from African, wild Asian, and domesticated Asian elephants. Details of the resultant successful use of NIRS for ivory identification have been published in *Conservation Science and Practice* (Chaitae et al., 2021). This chapter associates with **objective 1.3**.

Section 2: market interactions (chapters 5 – 6)

Chapter 5: Insights into the ivory supply chain and an estimation of stock provides information about the Thai ivory supply chain and factors influencing the supply to addresses **objective 2.1**. The annual raw ivory supply produced by domesticated elephants was based on government records. The corresponding manuscript has been published in *Human Dimensions of Wildlife* (Chaitae, Addison, et al., 2022).

Chapter 6: Ivory demand consumption and purchasing factors explores the consumption behaviour of ivory shop customers, including factors influencing their decision making. The resultant manuscript will be submitted for publication in a peer reviewed journal. This chapter addresses **objective 2.2**.

Chapter 7: Synthesis and discussion provides a summary of chapters 2 - 6 and discusses their key findings in the context of their potential to strengthen control measures for the domestic ivory trade in Thailand. This chapter discusses the management implications of my research in accordance with the overall aim of my thesis.

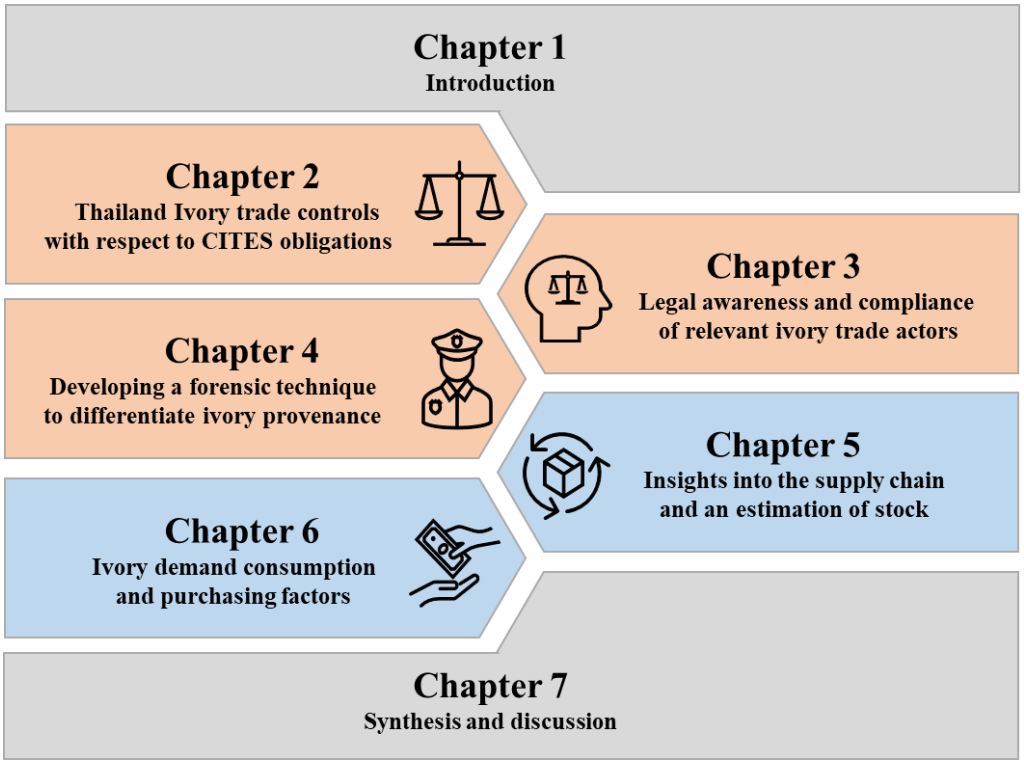


Figure 1.1: Schematic illustrating the structure of this thesis. *Colours represent sections of this thesis: grey; introduction and discussion chapters; orange: research chapters 2 - 4 address the control mechanisms; and blue: research chapters 5 -6 related to market interactions. This schematic is repeated on the introductory page of each chapter as an aid to the reader.*

My research is interdisciplinary and includes both natural and social sciences. The methodology involves three different main approaches: policy review, Near Infrared Spectroscopy and mixed methods, as summarized in *Figure 1.2*. Details are provided in the corresponding chapters.

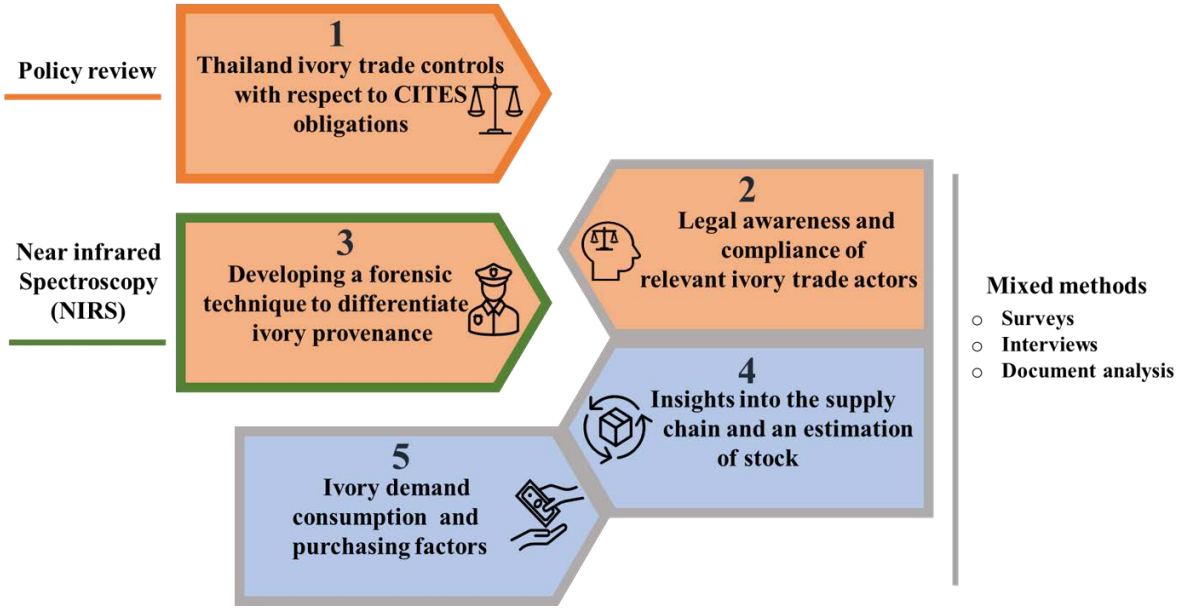


Figure 1.2: Methodology employed in the thesis.

1.6 Publications produced during my PhD candidature

- **Chaitae, A.**, Gordon, I. J. Addison, J., and Marsh, H. Protection of elephants and sustainable use of ivory in Thailand. (2022) *Oryx,* 56(4), 601 - 608 doi:10.1017/S0030605321000077
  (Chapter 2: Ivory trade controls with respect to CITES obligations)

- **Chaitae, A.**, Gordon, I., J. Marsh, H and Addison, J. *in prep*. Legal awareness of groups of actors in the Thai ivory trade chain.
  Target journal *Conservation & Society*
  (Chapter 3: Legal awareness and compliance of relevant ivory trade actors)

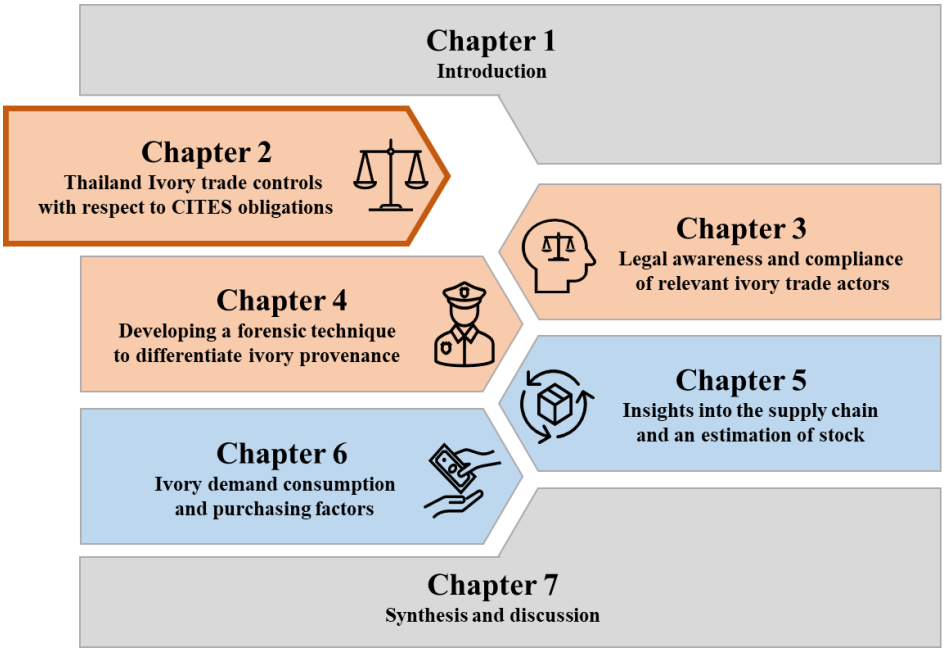
- **Chaitae, A.**, Rittiron, R., Gordon, I. J., Marsh, H., Addison, J., Pochanagone, S., and Suttanon, N. (2021) Shining NIR light on ivory: a practical enforcement tool for elephant ivory identification. *Conservation Science and Practice*, 3 (9). e486. doi:10.1111/csp2.486
  (Chapter 4: Developing a forensic technique to differentiate ivory provenance)

- **Chaitae, A.**, Addison, J., Gordon, I. J. and Marsh, H. (2022). Domestic ivory trade: the supply chain for raw ivory in Thailand is driven by the financial needs of elephant owners and market factors. *Human Dimensions of Wildlife*. doi:10.1080/10871209.2022.2143600
  (Chapter 5: Insights into the ivory supply chain and an estimation of stock)

- **Chaitae, A.**, Addison, J., Gordon, I. J. and Marsh, H. *in prep*. Ivory consumption: Factors influencing purchasing decisions made by Thai ivory buyers.
  Target journal *People and Nature*
  (Chapter 6: Ivory demand consumption and purchasing factors)

Chapter 2: Ivory trade controls with respect to CITES obligations

This chapter addresses objective 1.1 by providing the contextual background of the legal framework governing elephants and their ivory laws in Thailand. The chapter includes a literature review about the development and structure of the relevant laws, the 2015 legal reform, as well as the ivory trade control provisions stipulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). I then assess if the existing laws enable Thailand to comply with the obligations under the CITES convention as a member country.



Publication

A version of this chapter has been published as:

Chaitae, A., Gordon, I. J. Addison, J., and Marsh, H. Protection of elephants and sustainable use of ivory in Thailand. (2022). Oryx, 56(4), 601-608. doi:10.1017/S0030605321000077

2.1 Introduction

Ivory from African *Loxodonta* spp. and Asian elephants *Elephas maximus* has been traded for centuries (Feinberg & Johnson, 1982; Ibn Muḥammad Ibrāhīm, 1972; Kunz, 1916; Thailand's Fine Arts Department, 2013). Although Asian elephant ivory is less valuable than African ivory (St. Clair & Mclachlan, 1989), it is still highly valued and has been a source of income in Thailand for hundreds of years. Records can be traced back to the 14th and 15th centuries, with trade involving merchants from India, China, and Arabian and European countries (Ibn Muḥammad Ibrāhīm, 1972; Pallegoix, 2000; Thailand's Fine Arts Department, 2013). During the 17th–19th centuries, ivory was used to make musical instrument parts, art objects and high-value decorative items (Feinberg & Johnson, 1982; Johnson, 1978; Kunz, 1916; Walker, 2009). Carved products, made from imported raw ivory, were exported to Western and South-east Asian countries during 1800–1850 (Thailand's Fine Arts Department, 2013). After World War II, the predominant global destinations for ivory products shifted from Europe to Asia (Lindsay, 1986). Ivory markets in China and Thailand expanded significantly in the late 1980s and 1990s, coinciding with the development of regional economies and tourism in Asia (Stiles, 2004, 2009).

This significant global growth in demand for ivory led to increased killing and consequently population declines of African elephants (Wittemyer et al., 2014), and in 1989 the African elephant was uplisted from CITES Appendix II to Appendix I (CITES CoP7 Prop. 26, 1989; Sukumar, 2003). As discussed in Chapter 1, all Asian and most African elephants are currently listed in CITES Appendix I, and international commercial trade in their ivory is therefore banned (CITES, 1973, 2022a). Trade in ivory from African elephants listed in CITES Appendix II (populations from South Africa, Botswana, Namibia and Zimbabwe) is permitted under strict conditions (CITES, 2022a). Penalties for non-compliance with CITES regulations are harsh, and offending states face sanctions in the form of suspension of all international trade of any CITES-listed animal and plant species (CITES, 1973).

Thailand had high levels of illegal ivory trade during 2009 - 2011, largely because it lacked effective legal provisions to control trade in ivory sourced from Thailand’s captive elephants or to criminalize illegal ivory from Africa (CITES CoP16 Doc. 53.2.2 (Rev. 1), 2013). CITES recommended sanctioning Thailand by 31 March 2015, if it did not undertake satisfactory action to address this illegal ivory trade (CITES SC65 Com. 7,

2014). This prompted a revision of Thailand's National Ivory Action Plan, including legislative reform through the new Elephant Ivory Act (2015), to regulate trade in locally sourced ivory, and the listing of the African elephant as a protected species (CITES SC66 Doc. 29 Annex 8, 2015). This reform facilitates comprehensive monitoring of the ivory trade and allows authorities to address the illegal trade in African ivory. The resulting significant decrease in the domestic ivory market, together with large-scale seizures of smuggled ivory, eventually enabled Thailand to exit the National Ivory Action Plans Process (CITES SC70 Sum. 2 (Rev. 1), 2018). Nonetheless, as a country with a domestic ivory trade, Thailand continues to be bound to implement Resolution of the Conference of the Parties 10.10 (CITES Res.Conf. 10.10 (Rev. CoP18), 2019). Requirements include control of the domestic market to prevent illegal activities related to the international ivory trade, and recommendations to close the legal domestic ivory trade if it involves illegal activities in other countries (CITES Res.Conf. 10.10 (Rev. CoP18), 2019).

This review draws on peer-reviewed and grey literature to describe the challenge of managing elephants and ivory sustainably in Thailand, where such management is driven by a complex mix of cultural, livelihood and conservation values, and where there is a discrepancy between domestic needs and international obligations. I discuss the challenges of implementing the laws related to elephants and ivory in Thailand, and make recommendations to inform future conservation management.

2.2 Elephants in Thailand: past and present

Since the 13th century, Thai people have captured wild elephants and taken advantage of their strength and resilience for transportation, farm and forestry work (Ibn Muḥammad Ibrāhīm, 1972; Pallegoix, 2000; Pravorapakpibul, 1961; Thailand's Fine Arts Department, 2013). In historical times, elephants were also used to administer punishments, either to frighten offenders or execute criminals (Ibn Muḥammad Ibrāhīm, 1972). The establishment of the Elephant Department during the early Ayutthaya period (1420s) reflected the importance of elephants in warfare (Pravorapakpibul, 1961; Thailand's Fine Arts Department, 2013); during this time, kings went to battle on the backs of elephants (Thailand's Fine Arts Department, 2013), and there is still a unit under the Royal Office responsible for royal elephants (Thailand's Fine Arts Department, 2013). From the 1600s onwards, trained elephants were exported largely to India (Pallegoix, 2000; Thailand's Fine Arts Department, 2013). Trade in both elephants and ivory was permitted under the King's

administration until the initial period of Thailand's Rattanakosin Era in the early 1800s (De La Loubère, 1969; Thailand's Fine Arts Department, 2013). With technological advancements, the use of elephants as draught animals began to decline. Captive elephants in Thailand are now largely used in tourism (Phuangkum et al., 2005), but they still hold considerable cultural value (Thailand's Fine Arts Department, 2013). There are estimated to be c. 3,800 captive and nearly 3,500 wild Asian elephants in Thailand (*Asian elephant range states meeting 2017 final report*, 2017; Thailand's Department of National Parks, 2020).

In 1998 the Thai government designated 13 March as Thai Elephant Day, and in 2001 the Asian elephant was officially declared to be the national animal, to recognize the species' significance for the country's monarchy, history and culture (Thailand's Fine Arts Department, 2013; Thailand's Office of the Prime Minister, 1998, 2001). Elephants with distinctive characteristics (e.g., exceptionally pale or darker skin than usual) are legally recognized as so-called auspicious elephants and are required to be presented to the King under Wild Elephant Protection Act B.E. 2464 (1921). Auspicious elephants are a symbol of the power and authority of the King as a divine God, bringing propitiousness and agricultural productivity, and were also traditionally used for royal transport (Thailand's Fine Arts Department, 2013). Religious beliefs include the reincarnation of the Buddha as a white elephant (Sukumar, 2003). In addition, elephants have been depicted in various official symbols, including the national flag used during 1817–1917, with a white elephant in the centre of a red flag (Thailand's Fine Arts Department, 2013). The Kui people regard knowledge about elephants as an important part of ethnic identity, and a component of Thailand's cultural heritage (Thailand's Ministry of Culture, 2018).

The oldest ivory artefacts in Thailand date to almost 4,000 BCE (Na Nakhonphanom, 2013). Ivory carving was among the traditional Thai art forms dated from the Ayutthaya era. Later, Rattanakosin's Kings established a department producing traditional art pieces and utilities, including ivory carving, for royal use (Teanpewroj, 2015). Ivory has also been kept in temples for worship, and presented to revered persons, as some Thai people believe a supernatural spirit protects elephants (Bangkokbiznews, 2014). A pair of polished tusks, mounted on wooden bases, is often kept in Thai houses, near altar-tables or in meditation areas. A recent demand survey indicated that 2–3% of Thai people are ivory consumers, with ivory purchases often tied to their belief in its supernatural benefits (USAID Wildlife Asia, 2018). Jewellery is the most common ivory product found in Thai markets, followed

by sacred objects and decorative items, with individual items priced at Thai Baht 500–80,000 (c. USD 16–2,580) (Bank of Thailand, 2019; USAID Wildlife Asia, 2018).

Commercial ivory carving probably began in the late 1930s at Phayuhakhiri in Nakhon Sawan province in central Thailand, to satisfy the demand for worship items blessed by revered monks. Carvings included Buddha amulets, knives with ivory sheaths and handles, and animal figurines (Stiles, 2003, 2009). With the growth of tourism in Thailand in the 1970s, manufacturing shifted to products desired by foreigners such as jewellery, East Asian figurines and utilities, and expanded to adjacent areas ((Stiles, 2003). People in Uthai Thani, a nearby province, specialize in making steel and silver products decorated with ivory, and in Manorom in Chai Nat province, south of Phayuhakhiri, people carve Singha (lion figurines) and other sacred items (Stiles, 2009). In the north-east, Thatum in Surin province has many captive elephants and traditional knowledge about elephants and their training has been passed down through many generations of Kui people (Chomdee et al., 2013). In the past, raw ivory was mainly privately kept or sold as sacred items. Historically, some ivory was carved into Buddha figurines, but since the 2000s, commercial carving into a wide range of jewellery has become common in Thatum, to meet market demand.

Captive Asian elephants are a source of ivory in Thailand and other Asian countries such as Myanmar and Lao PDR (Sukumar, 2003; Vigne & Martin, 2017, 2018). In the past, the tusks of captive elephants were not usually cut, as the animals were left to roam freely in forests during periods when they were not required for work. There, the elephants used their tusks for defence, foraging and digging, which naturally shortens the tusk (Sukumar, 2003; Vanapithak, 1995). Now most captive elephants have less access to forests and limited use for their tusks. This can lead to tusks growing overly long or crossing over at the tips, which needs management for animal welfare reasons. Tuskers also face the risk of being killed or injured by ivory poachers. Prominent tusks are mainly produced by male elephants and grow throughout life (Sukumar, 2003), by c. 17 cm per year (Phuangkum et al., 2005). Tusks of live elephants are usually trimmed every 2 - 3 years from 15 years of age (Stiles, 2009), and whole tusks are removed from dead individuals (Chomdee et al., 2013; Phuangkum et al., 2005; Stiles, 2009). The price of elephant tusks, after the reform of ivory control laws, is fetched to Baht 40,000–60,000/kg (c. USD 1,290 - 1,935/kg; S. Arbhassarosakul, pers. comm., 2020) (Bank of Thailand, 2019).

Since the legislative reform in January 2015, the ivory trade in Thailand appears to be in decline. Whereas 339 shops trading ivory were identified prior to the January 2015 legislative reform, this number decreased to 117 by 2018 (CITES SC66 Doc. 29 Annex 8, 2015; CITES SC70 Doc. 27.4 Annex 21, 2018), and the quantity of products offered for sale in physical shops also decreased (Krishnasamy et al., 2016). However, the online trade is of concern and requires better law enforcement (Indraswari et al., 2020; Krishnasamy et al., 2016; WWF-Thailand, 2016). The shrinking of the ivory business is also evident in the decreasing number of active ivory craftsmen, mainly in Phayuhakhiri, one of the most important location for the manufacturing of ivory products: there were an estimated 50–100 in 1989, but only 50 - 60 in 2008 (Stiles, 2009). In the early 2000s, prior to the disruption of the illegal ivory trade by the Thai government in Phayuhakhiri, ivory carvers received a daily income of Baht 1,000 - 2,000 (c. USD 32–64). As trade restrictions reduced the demand for ivory carvings, some carvers began to work with other materials (e.g., wood, cattle and ostrich bones), and others ceased carving entirely (Bank of Thailand, 2019; MGR Online, 2018). The switch from ivory to cattle bone reduced the income of carvers by a mean of 35% (Stiles, 2003). In addition to the immediate effects on income, there is concern about the loss of the cultural knowledge of ivory carving (Stiles, 2003).

2.3 Elephant protection in Thailand

Elephant protection in Thailand (*Figure 2.1*) dates back to the 17th century, when Thai people were permitted to capture, but not kill, wild elephants (De La Loubère, 1969). Early legal provisions were designed to protect privately owned elephants (Draught Animals Act R.E.110, 1891), and included registration requirements, identification documents and import/export records. These measures are still in place (Draught Animals Act B.E. 2482, 1939; Pravorapakpibul, 1961, 1962).

Wild elephants are mainly protected by the Wild Elephant Protection Act and Wild Animal Reservation and Protection Act (WARPA). The former specifically imposes measures to protect wild Asian elephants such as controlling capture and procedures related to auspicious elephants (Wild Elephant Protection Act B.E. 2464, 1921; Wild Elephant Protection Act R.E. 119, 1900). The latter involves regulations concerning wildlife generally, and wildlife parts and products. It also prohibits hunting of any animals in protected areas (Announcement of the National Executive Council No. 228, 1972; Wild

Animal Reservation and Protection Act (No. 3) B.E. 2557, 2014; Wild Animal Reservation and Protection Act B.E. 2503, 1960; Wild Animal Reservation and Protection Act B.E. 2535, 1992; Wild Animal Reservation and Protection Act B.E. 2562, 2019).

Wild Asian elephants have been protected under WARPA since 1975, with a complete ban on commercial uses since 1992 (Ministerial Notification on prescribing possession limit of protected animals according to the Wild Animal Reservation and Protection Act B.E. 2503, 1976; Ministerial Regulation No. 4 (B.E. 2537) issuing under the Wild Animal Reservation and Protection Act B.E. 2535, 1994; Ministerial Regulation No. 10 (B.E. 2518) issued under the Wild Animal Reservation and Protection Act B.E. 2503, 1975; Wild Animal Reservation and Protection Act B.E. 2535, 1992). In 2015, the African elephant was the first non-native species to be added to the list of protected animals under WARPA (Ministerial Regulation on prescribing protected animals (No. 3) B.E. 2558, 2015). The Act does not apply to animals protected by the Draught Animal Act, including captive Asian elephants (Wild Animal Reservation and Protection Act B.E. 2535, 1992). WARPA was amended in 2019 to increase penalties and extend control over the possession and domestic trade of CITES-listed species (Wild Animal Reservation and Protection Act B.E. 2562, 2019).

Thai laws currently categorize elephants into three groups: captive Asian elephants (draught elephants and their offspring) are registered as draught animals under the Draught Animals Act, whereas wild Asian elephants and African elephants are protected species under WARPA (see *Table S2.1* for details).

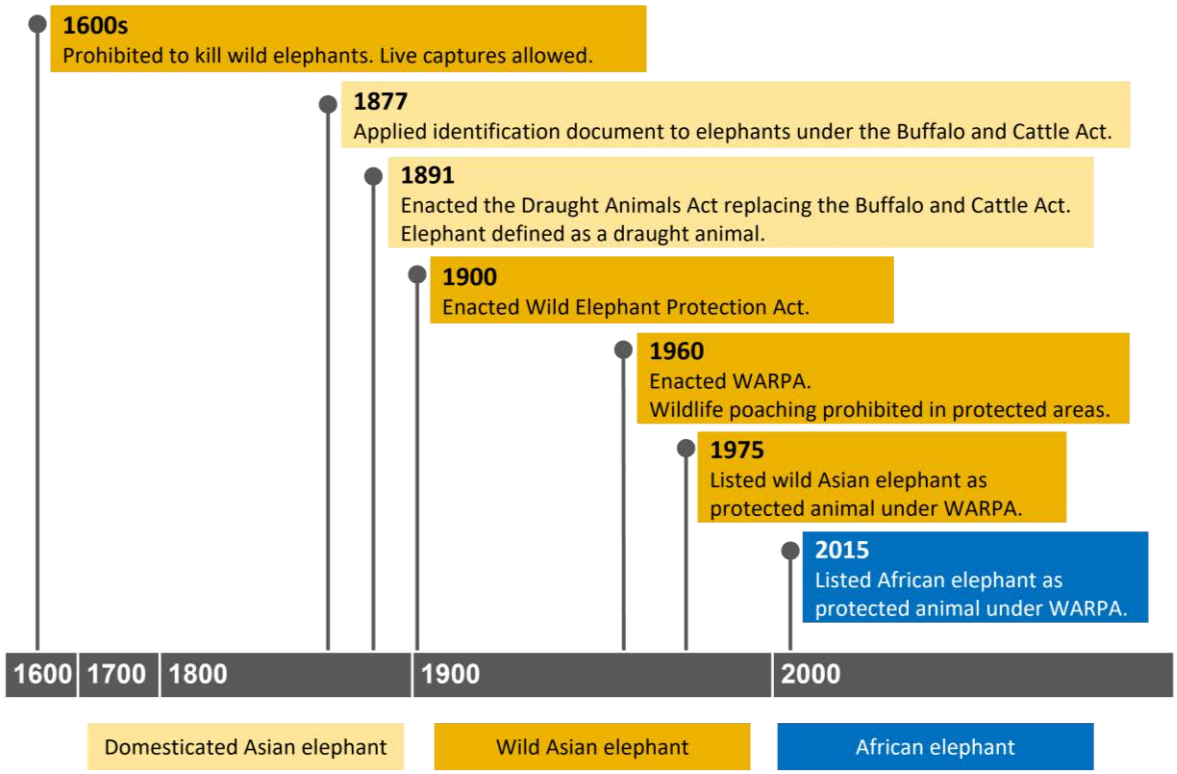


Figure 2.1: Timeline of the legal status of elephants in Thailand.
The timeline shows distinctive periods in the developing legal status of elephants. Asian elephants Elephas maximus have been considered as draught animals since 1891 (captive Asian elephant), and identification documents for elephants were employed more than a decade earlier. Regulations related to the capture of wild Asian elephant were prescribed by enactment of the Wild Elephant Protection Act R.E. 119 (1900). The wild Asian elephant has been protected under the Wild Animal Reservation and Protection Act (WARPA) since 1975, although hunting of all wildlife in protected areas has been prohibited upon the issuance of WARPA in 1960. The Act later included the African elephant (Loxodonta africana) in the category of protected animal, and this species now receives the same protection as the wild Asian elephant.

2.4 Legal framework for the regulation of ivory possession and trade

Current regulations regarding the transport, possession, domestic trade, import and export of elephant ivory in Thailand are complex and reflect the differences in the legal status of the three categories of elephants (*Figure 2.2*). Although the Wild Animal Reservation and Protection Act B.E. 2562 (2019), and the Elephant Ivory Act B.E. 2558 (2015) are the major laws controlling activities related to ivory, there are six additional laws that require enforcement by five authorities from four ministries (*Table S2.1*). Members of the Royal Thai Police also serve as enforcement officers under the two main acts. In addition, in 2013 the illegal exploitation of natural resources for commercial purposes (including ivory-related activities) was included as a case offense under the Money Laundering Control Act B.E. 2542 (1999), thereby allowing proceedings for asset forfeiture in addition to prosecution under the main laws (Money Laundering Control Act (No. 4) B.E. 2556, 2013). Illicit export or export of ivory may also result in prosecution under the Prevention and Suppression of Involvement in Transnational Crime Organization Act B.E. 2556 (2013).

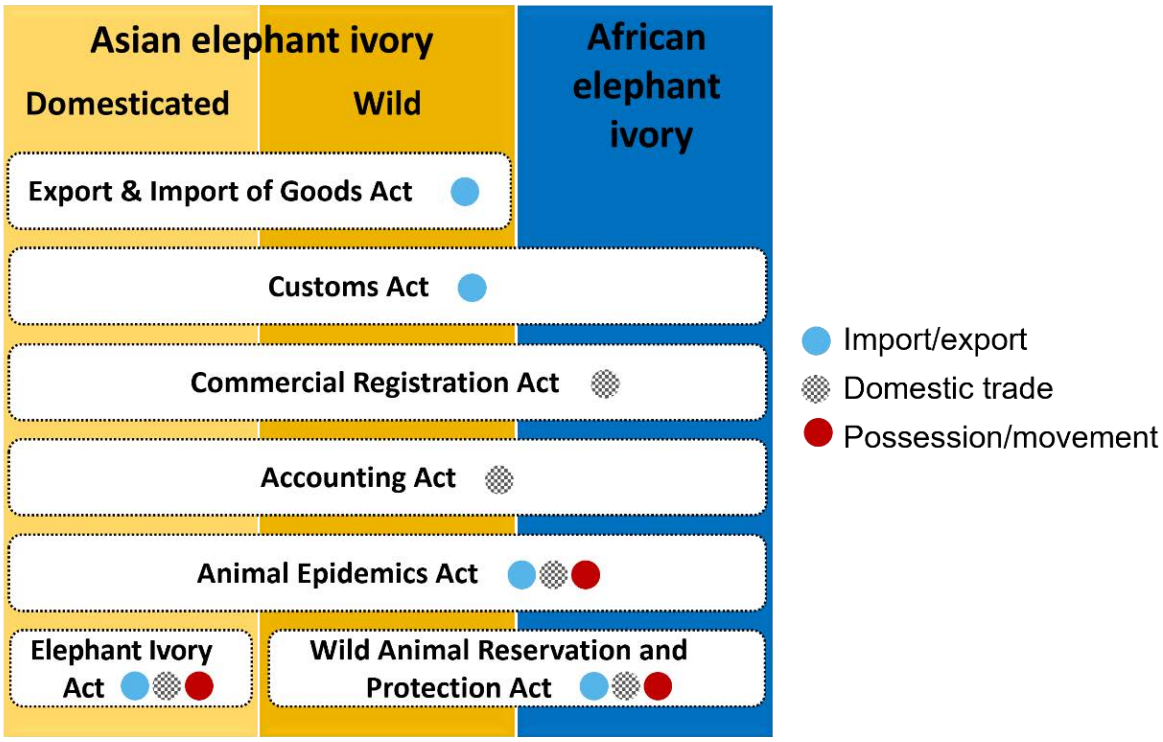


Figure 2.2: The complexity of current legislation for the three types of ivory in Thailand. *Activities relating to ivory from domesticated Asian elephants are mainly regulated by the Elephant Ivory Act and five supportive laws. Wild Asian and African elephants are protected under WARPA, thus activities involving these ivory types are governed by six and five pieces of legislations, respectively. Export regulations under the Export and Import of Goods Act are only applied to Asian elephants. Regulations concerning key activities such as possession, transport, domestic trade, export and import vary among ivory types.*

The Elephant Ivory Act B.E. 2558 (2015) requires ivory to be registered, with information including evidence of ivory acquisition i.e., a certificate of origin for elephant ivory issued by registrars of the Draught Animal Act (Thailand's Department of National Parks, 2017). People who possess ivory must notify the relevant official of changes in ownership, place of possession and ivory modification or manufacturing. Inter-provincial movement of raw ivory also requires a permit, upon presentation of the certificate of origin for elephant ivory, according to Animal Epidemics Act B.E. 2558 (2015). Trade in ivory is controlled by at least three different laws: (1) permission and compliances under the Elephant Ivory Act (2015) (Ministerial Regulation on permission application, 2015), (2) registration under the Commercial Registration Act B.E. 2499 (1956) (Notification of the Ministry of Commerce on registration requirement of business (No. 8) B.E. 2547, 2004), and (3) accounts keeping under the Accounting Act B.E. 2547 (2000) (Notification of Ministry of Commerce on prescribing the duty of accounts maintenance for ivory-related entrepreneurs B.E. 2551, 2008). A trade permit under the Animal Epidemics Act B.E. 2558 (2015) is also required if trade involves raw ivory.

Specific official permits are required by law for the export and import of all three types of ivory; however, permission is granted only for non-commercial purposes. Import and export permits are required under the Elephant Ivory Act B.E. 2558 (2015) for the ivory obtained from draught elephants, and WARPA permits are mandatary for ivory from wild Asian and African elephants (Wild Animal Reservation and Protection Act B.E. 2562, 2019). In addition, the export of Asian elephants (both wild and captive), including their parts and derivatives, requires a permit under the Export and Import of Goods Act B.E. 2522 (1979) (Notification of the Ministry of Commerce on specifying elephant as a goods required a license prior to export B.E. 2555, 2012). All elephants are also governed by the Animal Epidemics Act B.E. 2558 (2015), and export and import permits are required for raw elephant ivory. Given the legal provision of ivory, import and export of all ivory types must also comply with the Customs Act B.E. 2560 (2017).

2.5 Discussion

In circumstances such as those in Thailand, ivory could be treated as a renewable resource, the sustainability of which is achieved through a highly-regulated legal trade. The reformed Thai legislation regarding ivory has the potential to align with both the principles of the CITES convention and Thailand's economic interests and cultural value, if barriers to enforcement can be overcome. The complex nature of current legislation regarding ivory-related activities makes compliance difficult. For example, the way in which certificates of ivory origin are issued, and the implementation of relevant regulations, largely depends on the legal understanding of local registrars (S. Arbhassarosakul, pers. comm., 2018). The permit for inter-provincial movement is issued only after the presentation of a certificate of origin (Notification of the Department of Livestock Development on prescribing criteria, 2015). However, certificates cannot be issued retrospectively, which makes interprovincial movement of old stocks of ivory (pre-2015) impossible. The need to visit a regional office to register ivory possession presents barriers in the form of travel costs and time, an effort that is difficult to justify particularly for small ivory items (S. Arbhassarosakul, pers. comm., 2018). For ivory traders, certain legal requirements posed by the Accounting Act and Elephant Ivory Act create a procedural burden. There is thus a need to streamline the legal framework and consolidate laws related to elephants and ivory. This change would not only reduce the administrative effort for traders, but also facilitate product registration for buyers, thereby contributing to increased compliance.

Legal domestic ivory markets that contribute to poaching or illegal trade need to be closed as a matter of urgency (CITES Res.Conf. 10.10 (Rev. CoP18), 2019). Enforcement efforts are essential for maintaining a closed Thai domestic market, as the activity of illegal businesses is directly influenced by the effectiveness of law enforcement. Comprehensive trade controls should prevent both the entry of illegally sourced ivory into the domestic market and the export of ivory products from the country. Significant effort is required to monitor the online trade, because illegal online commerce could hamper the control of the legal trade. The new WARPA can facilitate the prosecution of people involved in the illegal online trade of ivory (Wild Animal Reservation and Protection Act B.E. 2562, 2019). The use of electronic databases and software systems could help monitor the trade and enable information exchange amongst relevant authorities.

Ivory identification is a challenge for enforcement officers, and the use of modern technologies could facilitate this. Considering the three types of ivory covered by Thai laws, practical tools to differentiate between them are needed to ensure effective control of the ivory trade. Samples of DNA from domesticated elephants (CITES SC70 Doc. 27.4 Annex 21, 2018) would facilitate verification of ivory from domesticated individuals. Advances in technology (e.g., analysis of chemical composition and genetics) potentially offer methods for distinguishing ivory from different species and locations, based on diet, habitat use and genetics (Raubenheimer et al., 1998; Shimoyama et al., 2004; Wasser et al., 2008; Ziegler et al., 2016). Spectroscopic techniques could offer simple and non-destructive ways to assist field officers in identifying ivory (Buddhachat et al., 2016; Shimoyama et al., 2004). Isotopic analyses are effective in differentiating between wild and captive animals of the same species such as wolves *Canis* spp. and pythons *Python* spp. (Kays & Feranec, 2011; Natusch et al., 2017). The development of practical techniques for distinguishing ivory from domesticated elephants from that originating from illegal sources would strengthen the enforcement capacity of Thai authorities (Chaitae et al., 2021; Chapter 4).

Given that the legal ivory trade in Thailand requires a supply from local domesticated Asian elephants, the domestic ivory trade could be sustainable if locally sourced ivory can satisfy local demand. Understanding the nature of local consumption would provide a reference for evaluating the capacity of local ivory stock to meet this demand.

2.6 Chapter summary

- The historical relationship between elephants and culture influences the legal framework regarding elephants and ivory in Thailand. Thai laws allow the exploitation of domesticated elephants and ivory as private assets, although the country is bound by CITES provisions for international activities. Ivory from African elephant and wild Asian elephants is completely protected from commercial uses by laws.

- Prior to 2015, the lack of comprehensive measures to control the Thai ivory market enabled the laundering of illegally sourced ivory in the country resulted in the legislation review in 2015. The laws now enable comprehensive control over the possession and domestic trade of ivory from domesticated Asian elephants, and aligning the protection of African elephants and their ivory with CITES regulations.

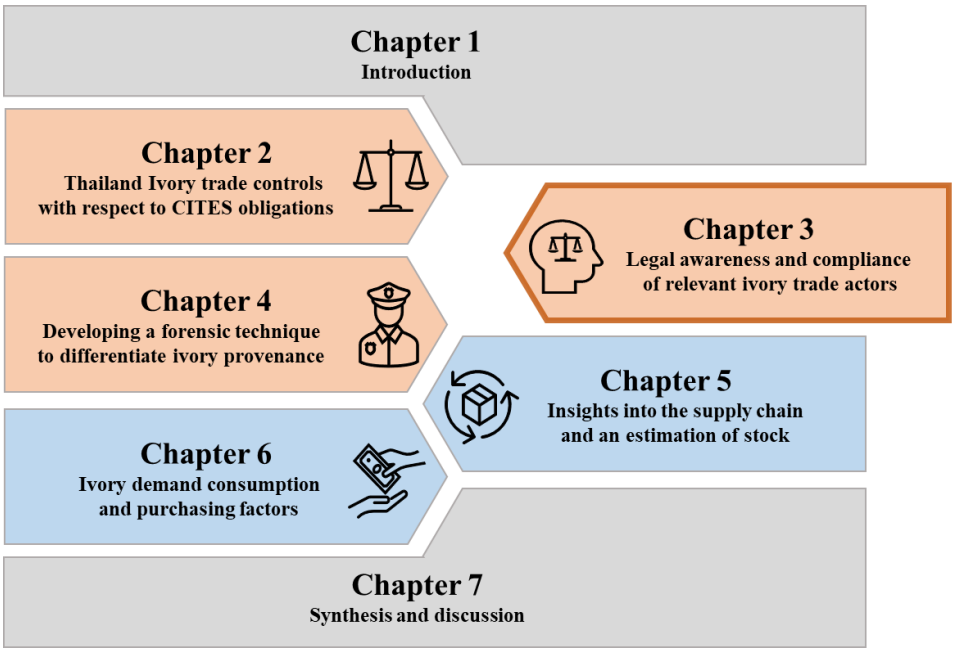
- However, the complexity of the legal system presents barriers to effective implementation due to confusion and legal complexity, as well as a high transaction cost.

- Integration of relevant regulations, especially those specifically related to control of live elephants, their parts and products of domesticated elephants, into a single law could benefit law enforcement and compliance in the long run. In the interim, simplifying existing regulations may facilitate compliance.

- Moreover, use of an electronic database would improve the monitoring of ivory movements and aid the implementation and enforcement of laws.

Chapter 3: Legal awareness and compliance of relevant ivory trade actors

Ivory trade control measures can be strengthened by the compliance of relevant actors. To achieve compliance, it is important that relevant actors have knowledge of relevant laws. Given the complex legislation documented in the Chapter 2, I further explore the legal understanding of groups of key actors (elephant owners, ivory traders, and ivory consumers) related to their activities in the trade. I use interviews and survey to collect data from the three main groups of actors in different regions of Thailand. This research enables an understanding of the current awareness of these actors and could inform strategies to enhance their knowledge, and thus compliance. I also explore the compliance of a group of ivory consumers using the Unmatched Count Technique (UCT).



Publication

A version of this chapter will be submitted for publication as:

Chaitae, A., Gordon, I. J. Marsh, H., and Addison, J. *in prep*. Legal awareness of groups of actors in the Thai ivory trade chain. *Conservation & Society*

3.1 Introduction

Legal awareness is an initial step to achieving compliance with relevant laws (Keane et al., 2011). Some people voluntarily obey the law as they accept the rules based on their normative view; compliance is also frequently obtained via punishment and enforcement (Tyler, 1990). Awareness can deter illegal behaviours; for example, wildlife poisoning was low among pastoralists in Kenya who were likely aware of the measures and punishments outlined in the relevant law (Didarali et al., 2022). Knowledge of regulations is important regardless of the compliance mechanism. Such knowledge is often inadequate among actors (Fukushima et al., 2021; Keane et al., 2011; St. John et al., 2015). Around half of Cambodian hunters were either unaware or mistaken about the rules concerning using snares around farms (Ibbett, Keane, et al., 2021). Varied understanding of fisheries regulations is common, resulting in non-compliant fishing (Collins et al., 2021). Similarly, Davis et al. (2016) found that locals in Luang Prabang had less knowledge of the laws around protection of bears, *Ursus thibetanus* and *Helarctos malayanus,* than Chinese visitors did. Along with perception, legal awareness can influence compliance (van Rooij, 2021). It is crucial that actors have sufficient understanding of relevant laws.

As explained in Chapter 2, legislative control of the Thai ivory trade involves implementation of multiple laws. In this chapter, I further explore the legal understanding of the actors in Thailand's ivory trade chain. I know of no other assessment of the legal knowledge across key actors in the ivory trade since the implementation of reforms in Thailand in 2015 (see Chapter 2 for the details of the reforms). I also assessed the legal compliance of a group of ivory consumers using the Unmatched Count Technique (UCT). UCT (also known as the List Experiment) has been used for studying sensitive topics in various disciplines including conservation research concerning wildlife consumption (Davis et al., 2019; Nuno et al., 2018), hunting (Ibbett, Keane, et al., 2021), and trade (Hinsley et al., 2017). These findings are designed to inform policies aimed at enhancing the legal awareness of the key actors as an important step toward achieving higher levels of compliance with Thai ivory laws.

3.2 Methods

3.2.1 Data collection

I structured the data collection in accordance with the roles of the actors in the ivory supply chain (*Figure 3.1*) using different approaches with different groups of actors (elephant owners, ivory traders, and ivory consumers) taking account of the expected variation in their literacy and accessibility.

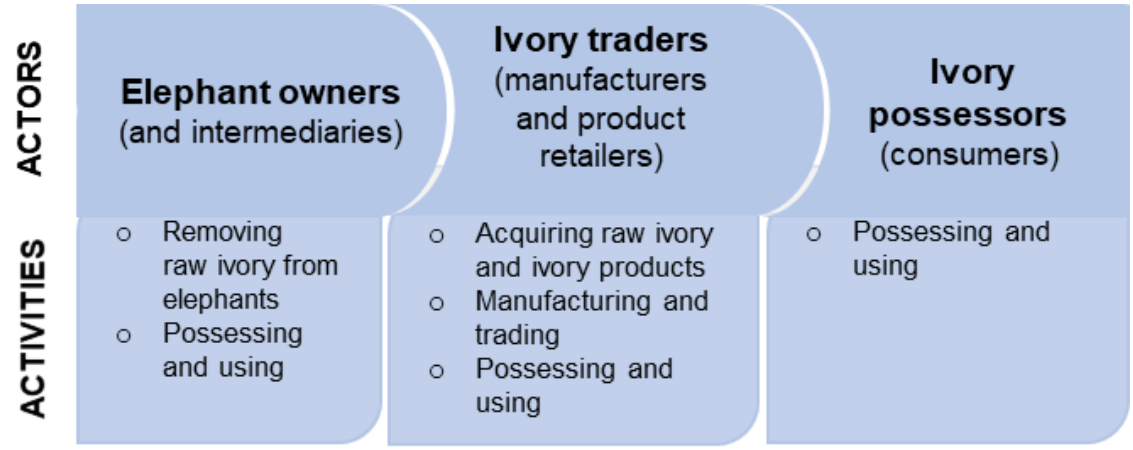


Figure 3.1: A framework of key actors and their potential activities in relation to ivory.

3.2.1.1 Elephant owners and ivory traders

Data were collected between November 2019 and February 2020 in four regions of Thailand to cover regional variation, see *Figure 3.2* for locations and general description of sampling areas in *Table 3.1*). I conducted semi-structured interviews in Thai, with elephant owners and ivory traders (*Info S3.1*). All interviewed participants gave verbal consent to be interviewed anonymously and audio recorded, as approved by the James Cook University Human Ethics Committee (H7873). Verbal consent was obtained due to the combination of poor literacy of potential participants, and their potential hesitancy in signing documents.

Twenty-three elephant owners were recruited from the North (5), Northeast (13), and South (5) using purposive and snowball sampling, and were interviewed face-to-face, or via telephone. Elephant owners were asked about their knowledge of the laws pertaining to cutting or removing raw ivory from elephants, as well as other activities such as transferring ownership and moving ivory across provinces.

I conducted face-to-face interviews with 17 ivory traders (11 manufacturers and 6 product retailors), from the North, Northeast, and Central regions, based on my pre-existing contacts followed by snowball sampling. Interview questions focussed on ascertaining the traders' knowledge of the legal requirements regarding trading ivory, and the ways in which they learnt about these requirements.

3.2.1.2 Ivory consumers

Ivory consumers were surveyed in Thai to elicit information about the following: i) their awareness of the laws relevant to ivory-related activities, ii) their compliance with Thai ivory laws, using the Unmatched Count Technique (UCT), and iii) demographic information (*Info S3.2*).

1,500 anonymous ivory possessors residing in Bangkok (750 males and 750 females), who had previously provided their postal address to the Thai Department of National Parks, Wildlife and Plant Conservation (DNP), were randomly selected by Department officers from the database of the domesticated elephant ivory registration comprising ~45,000 possessors. The surveys were posted to the addresses of participants with an invitation letter, an information sheet, and a stamped envelope for returning the survey to an assigned postbox. Informed consent was given in the form of implied consent as completion of the questionnaire was voluntary and participants were anonymous, as approved by the James Cook University Human Ethics Committee (H7927). The study was conducted between May 2020 and May 2021.

Legal awareness

I studied the legal understanding of each ivory possessor via two principal questions:

- Question 1 ("tradable status of ivory"): Can any of these types of ivory (African, wild Asian, and domesticated Asian elephants) be legally traded within Thailand? The aim of this question was to assess whether the respondents understood the different legal status of the three ivory types (sourced from African, wild Asian, and domesticated Asian elephants).
- Question 2 "ivory-related restrictions": Do any of the following activities require an appropriate authorization? Activities included trading ivory as a business, wearing ivory jewellery out of/into Thailand, owning a piece of raw ivory, importing or exporting of ivory out of/into Thailand, trimming tusks from a domesticated

elephant, carving/cutting registered ivory, translocating registered ivory. The aim of this question was to explore the ivory consumers' awareness of the legal details of key activities relevant to them.

Each question included terms or statements, to which the participants were asked to mark "yes", "no" or "do not know". The "do not know" option enabled respondents to express their uncertainty regarding any question; "yes" or "no" answers should reflect more confidence.

Legal compliance (Unmatched count technique - UCT)

I used four sets of statements to assess four aspects of the legal compliance of ivory consumers: possession of ivory, ivory purchasing, ivory sales, and smuggling. Respondents were randomly allocated into control and treatment groups of equal size for each aspect (two groups). The control groups received the version of UCT survey that contained only non-sensitive statements, whilst the treatment respondents received the same set of non-sensitive statements plus one statement about breaking laws (sensitive statement).

For each list, each respondent reported only the number of statements applying to them. Thus, the respondent did not identify which statement(s) (sensitive or non-sensitive) were relevant to them. I used a pilot study to select the non-sensitive statements for the main study. Non-sensitive statements were developed around ivory-related activities that were familiar to ivory consumers, to sensitive statements to blend in with them. The final non-sensitive statements for each list contained a pair of negatively-associated statements and a pair with a mixture of high and low prevalence statements to avoid ceiling (all statement selected) and floor (no statement selected) effects (Glynn, 2013). I piloted the surveys with the first 100 participants; the remaining 1400 participants were used for the main phase, resulting in 27 completed responses from the pilot phase and 470 from the main study (total response rate = 33%).

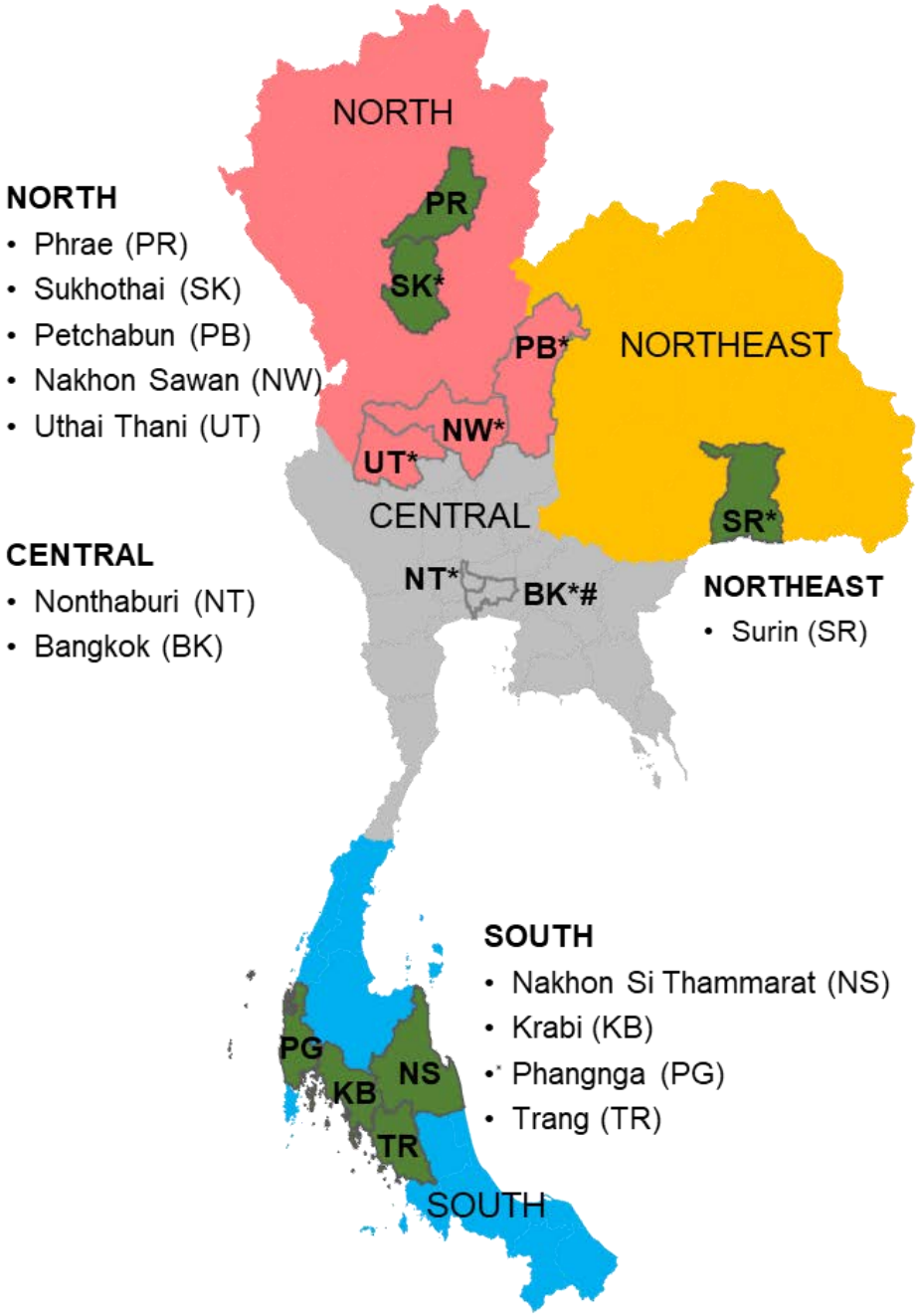


Figure 3.2: Map showing sampling areas in four different regions of Thailand.
*Green coloured provinces show sampling areas for elephant owners, province names with * indicate ivory trader sampling, and # indicates location of the ivory consumer respondents.*

Table 3.1: General description of sampling areas related to ivory trade chain. *See Figure 3.2 for locations.*

Region & Province	Description
North • Phrae • Sukhothai • Nakhon Sawan • Uthai Thani • Petchabun	Elephants mostly work in the tourism industry. These elephants are either locally-owned, or have owners based elsewhere e.g., Surin (Tipprasert, 2002). Nakhon Sawan and Uthai Thani are currently important ivory product manufacturing areas. Ivory carving business in Thailand started from these areas with early stage of production involving sacred items and later expanded to a wide range of jewellery and products (Stiles, 2003).
Central • Bangkok • Nonthaburi	Most ivory consumers in Thailand live in Bangkok (Krishnasamy et al., 2016). There are ivory retailers in Bangkok and metropolitan areas, including Nonthaburi.
Northeast • Surin	Thatum in Surin is known to be the 'home of the domesticated elephant'. Elephant keeping is an important cultural and livelihood value for the Kui ethnic group (Chomdee et al., 2013). Surin elephants either remain locally or work in tourism businesses in other area (Tipprasert, 2002). Surin is another significant manufacturing site (Krishnasamy et al., 2016). There are about 40 registered ivory traders in Surin, most of whom are centred at the Ta-klang elephant village in Thatum ("Deputy commissioner-general visited the city of elephant for inspecting ivory businesses ", 2016).
South • Nakhon Si Thammarat • Krabi • Phangnga • Trang	There are many elephants working in elephant camps (elephant tourist businesses) in tourist hotspots (e.g., Phuket), which largely originated from Northern provinces and Surin of Northeast. Some the elephants log in the rubber plantations (Chotikasemkul, 2019; "Elephants from the North and the Northeast increasingly moved to the South to support tourism and labour uses," 2017; Tipprasert, 2002).

3.2.2 Analysis

3.2.2.1 Elephant owners and ivory traders

Legal awareness

All interviews were conducted and transcribed in Thai to preserve the contextual meanings and perspectives of the participants. Quotations that are part of the Results are presented in English. The translation of these quotations represents the meaning expressed by the participants for research validity (van Nes et al., 2010). Description and language amendments to facilitate reading are in square brackets. Coding was conducted in English using NVivo (QSR International Pty Ltd., 2018). I conducted open coding to generate concepts and categories for refining perception and attitudes toward the laws. Different parts of each transcription were coded and marked with appropriate labels for identification during analysis (codes). The codes were further grouped under the same category based on relationship and similarity.

3.2.2.2 Ivory consumers

Legal awareness

I used Chi-square tests to compare respondent demographics with that of the broader Thai population (National Statistical Office, 2018 2021). For assessing legal awareness, the answers for each sub-question were marked and counted as “correct”, “wrong”, and “do not know”. Overall understanding of ivory regulations was based on the number of correct answers (score) achieved by the 497 respondents. The relationship between respondent characteristics and their overall legal awareness was analysed using non-parametric tests as the data were not normally distributed. The Mann Whitney U test was used for comparing between genders, while the Kruskal-Wallis test was used to compare between multiple categories. Due to the small sample sizes in certain categories (*Table 3.2*), I recategorized data according to age class and ivory possession volume to enable statistical testing (*Table 3.3*). Religious information was excluded from the relationship analysis due to the overwhelming dominance of Buddhists (97.2%). I calculated the correct to non-correct ratio to represent the knowledge level of respondent categories. “Wrong” and “do not know” answers were combined as non-correct responses. Thus, higher ratios indicate correct understanding of the law. Statistical analyses were performed sing IBM SPSS Statistics 27 (IBM Corp, 2020).

Legal compliance (Unmatched count technique - UCT)

Analysis was conducted using the 470 responses obtained from the main study using the List package 9.2 of Program R (Blair et al., 2020; R Core Team, 2021). The difference-in-means between the control and treatment groups was calculated using the *ictreg* function to provide prevalence estimates of law-breaking behaviour (Blair et al., 2020). This function has been specifically used to conduct multivariate regression analyses of survey data using UCT. I explored design validation using *ict.test* function with the null hypothesis of no design effect which occurs when response of individual to the non-sensitive items changes upon the treatment status (Blair et al., 2019; Blair & Imai, 2012).

3.3 Results

3.3.1 Elephant owners

Elephant owner interviewees were generally aware of the ivory laws, apart from a few unclear and misunderstood aspects. Their legal awareness included the requirements related to obtaining raw ivory from their elephants, and transportation and registration of ivory. Elephant owners involved in trading showed a higher understanding than those not involved with trading. Most elephant owners were positive about the Elephant Ivory Act 2015 despite some complaints about the complicated legal provisions.

Surin elephant owners demonstrated a more accurate understanding of the regulations than owners from South Thailand did. For example:

> *Today, there is the ivory law. There is an inspection by district office for issuing document about origin of ivory. Then we can register the ivory at the DNP office at Ubol Rachathani. Having these documents is good for elephant owners, no one steals tusks from elephants as no registration can be done, it is worthless. If I sell or give it to someone, cut [tusks], or move to a new place I have to inform the Ubol Rachathani office.* [EO11, Surin]

Legal knowledge was also high among elephant owners who acted as intermediaries in the supply chain, searching for ivory within their local area or through established connections. These elephant owners learnt from their trader contacts.

> *[We] either cut ivory or once took from a dead elephant, we have to inform a district office, and then register with a forestry office [DNP] by 30 days. We did not inform an officer in early days when cutting ivory, but very strict now. Officers check if it is legal ivory. Transferring to someone have to be done at the forestry office too. There is a fine for the delay, it is expensive. At first, I was confused about many offices to contact. The ivory trader, I help them sourcing ivory, told me what I have to do.* [EO13, North]

Besides their legal understanding about the regulations relevant to their activities, some owners demonstrated knowledge of trade permit requirements, the illegal status of African ivory compared with domesticated ivory, prohibition of exporting and importing ivory, and compliance with CITES. For example:

> *The law aims to prevent bringing in foreign [African] ivory to follow CITES. This created a better control. Trading ivory have to get a permit. An ivory document shows about where ivory is from. It is hard to get illegal ivory into the system.* [EO9, Surin]

In contrast to elephant owners from Surin, owners residing in the South and the North (*Figure 3.2*) had incomplete or mistaken knowledge about the need to register raw ivory with DNP. They believed that the registration of raw ivory under the *Elephant Ivory Act 2015* was required only under certain circumstances rather than always being mandatory. Southern elephant owners and their connections demonstrated similar misunderstandings.

> *If the cut tusk weight is less than half of kilo, [there is] no need to inform a forestry office [DNP]. Those tusks sometimes were small, either were cut or accidently broken. We must register, only, tusks took from a dead elephant, they were large, with a forestry office within 30 days otherwise we are guilty and must be fined. I have to contact the forestry office again when selling the tusks.* EO18, South

> *I learned that we must have evidence and pictures when cutting tusks to get an ivory certificate issued by a district office. It is all done, [we have] no more contact with other offices.* [EO22, North (native to the South)]

Some owners demonstrated a lack of clarity about the details and procedures required by different legal frameworks. These respondents have not cut elephant ivory since the introduction of the new law. They expected a clear understanding from contacting officers, ivory traders and other elephant owners.

> *We must inform officers everything about ivory, but do not know how to do. [Ivory] traders know well, I will sell [ivory] to them, they will help me do this. Since having the law, I have not cut ivory yet.* [EO12, Surin]

> *Livestock Development officers taking care of my elephants told me that I have to inform a district office and Livestock Development office. I am not sure in details, never do this.* [EO23, North]

An elephant owner, who was an intermediary, explained the problems with information access for certain groups of elephant owners, a factor contributing to their lack of legal awareness and compliance.

> *Some elephant owners live in remote, mountainous areas of the North. Many of them are not educated, so they only learn from asking others. When people do not understand, so they worried about being arrested, and then avoid participation. I explained to people I contacted with, about law, so they knew. There are still this groups of elephant owners [who are] unsure about law. It is so confused for general elephant owners.* [EO13, North]

3.3.2 Ivory traders

Overall, the traders showed strong knowledge of the laws related to obtaining raw ivory, manufacturing ivory into products, and selling ivory items to retail customers. Their most frequent responses about trading regulations related to obtaining legal ivory for manufacturing, the keeping of records and reports, and the issue of ivory sale certificates to customers. They obtained their legal knowledge from the training provided to them by government officers, casual inquiries, and regular monitoring measures. They also educated their contacts, including elephant owners and ivory buyers, about the regulations.

Ivory businesses can be involved in manufacturing and/or retailing of finished products. Ivory traders in Nakhon Sawan, Uthai Thani and Surin are important manufacturers, producing ivory products from raw material. Their businesses involve both wholesaling to

other ivory traders and retailing ivory items to general customers. Their legal knowledge thus covered a wide range of such activities and they transferred information to elephant owners and ivory buyers during trade activities.

> *For registering raw ivory with the DNP, I need the ivory certificate from a district office [Department of Provincial Administration]. A movement permit from Livestock Development office is needed when I moved ivory from other provinces into my shop. When we manufacture into products, I have to report for inspection before selling. The ivory shop must report all records by the 10th each month. We have to show the trade permit. New buyers mostly ask me about ivory, is it real, how to distinguish ivory, is it from a legal source or if elephants were killed. But for existing buyers, they trust us, then [we receive] no such questions from them. We always give buyers the document so they can register ivory bought from us, the document is the evidence of ivory legality and authenticity.* [TM12, Uthai Thani]

> *I once travelled up North to collect a pair of tusks from a dead elephant. The owner gave me a document certified by a police officer, which cannot be used for proofing legality of ivory. I told them to get the right documents and register ivory as the law needs. ... I explain [the law to] many elephant owners who do not understand the law well.* [TM3, Surin]

> *I give customers the document [ivory sale certificate] for registering their ivory items. I tell them to contact a DNP office responsible for their residential areas within 30 days. Then they, very frequently, complain about timing, distance, and complication of procedures. Everyday, I have to answer customers' question about laws related to ivory, and if ivory is real. Before, they did not ask about law.* [TM17, Nakhon Sawan]

Retailors were well aware of legal requirements related to selling the ivory products:

> *I bought products from a shop at Nakhon Sawan. I used the document as legal evidence for my stock. I do not do any manufacturing, just sell what I got. What I have to do is report the sale record every month and issue the document for the customer.* [TR13, Bangkok]

Some other restrictions noted by traders include export prohibition and the fixed location of ivory shop:

> *I do not sell ivory to foreigners, because it is not allowed to be exported*. [TR14, Nonthaburi]

> *I told my customers that they cannot wear it when traveling to other countries. This ivory is only for use in the country, CITES does not allow it.* [TR9, Sukhothai]

> *Today, we are not allowed, by law, to sell ivory at any temporary events or markets as we did before. We lost many customers. I can trade only here at my shop.* [TM8, Nakhon Sawan]

Misunderstandings by traders about their about legal requirements were illustrated by statements such as "*Customers have to register their bought items within 15 days*" T5, Surin, and "*Buyers cannot sell their bought ivory because they do not have an ivory trade permit*" T15, Nakhonsawan. Actually, ivory must be registered within 30 days of acquisition, whereas occasional ivory sales by private users is not considered to be commercial trade and no trade permit is needed.

Ivory traders highlighted the mechanisms by which they gain legal understanding:

> *Officers come to my shop every month; they check records and give me advice about doing all the paperwork.* [TM1, Surin]

> *At first, we did not understand regulation well, it was hard. DNP office did some workshops and taught us about doing records the law needs. I regularly do it, so now, I understand and can do all paperwork myself.* [TM3, Surin]

3.3.3 Ivory consumers

3.3.3.1 Respondent characteristics

The gender, age class and religious affiliation of my sample of ivory consumers in Bangkok differed from the Bangkok and national populations (*Table 3.2*). Ivory consumers, who responded to my survey, were disproportionally male (51%) and older than 60 years (56%). Their modal education level was a Bachelor's degree. About half of the respondents were retired or did not work. Most (60%) possessed 1 - 4 pieces of ivory.

Table 3.2: Characteristics of ivory consumers in Bangkok and results of Chi squared tests comparing their demographic profiles with the Bangkok and national populations for gender, age class and religion.

Characteristic	Category					Chi-square test	
						Value	*p*
Gender	**Male**	**Female**					
Study respondents	254 (51.1%)	243 (48.9%)				6.210	0.013
Bangkok residents[1]	45.50%	54.50%					
Age class (years)	**21 - 30**	**31 - 40**	**41 - 50**	**51 - 60**	**≥61**		
Study respondents	6 (1.2%)	30 (6.0%)	63 (12.7%)	118 (23.7%)	280 (56.3%)	334.327	<0.001
Bangkok residents[1]	17%	18%	20%	19%	25%		
Religion	**Buddhist**	**Christian**	**Muslim**	**None***			
Study respondents	483 (97.2%)	11 (2.2%)	2 (0.4%)	1 (0.2%)		28.753	<0.001
National residents[2]	93.50%	1.10%	5.40%	-			
Education level	**Primary school**	**High school**	**Diploma**	**Bachelor**	**Graduate**		
Study respondents	17 (3.4%)	53 (10.7%)	26 (5.2%)	209 (42.1%)	192 (38.6%)		
Occupation	**Do not work**	**Business owned**	**Private employee**	**Government employed**			
Study respondents	245 (49.3%)	142 (28.6%)	76 (15.3%)	34 (6.8%)			
Possessed ivory quantity (pieces)	**1 - 4**	**5 - 10**	**11 - 15**	**16 - 20**			
Study respondents	282 (60%)	91 (19.4%)	32 (6.8%)	12 (2.6%)			
	21 - 25	**26 - 30**	**≥31**				
	11 (2.3%)	8 (1.7%)	34 (7.2%)				

*Note: [1] 2021 demographic data of Bangkok residents aged 21 years old and above (National Statistical Office, 2021), [2] 2018 religious affiliation of the total population in Thailand (National Statistical Office, 2018), * "None" category of religion excluded from Chi square test due to the unavailability of comparable data.*

3.3.3.2 Legal awareness

Twenty-three percent of my sample of 497 ivory consumers were aware of the different legal status of the three ivory types (score 3); 19% of them had no knowledge about this provision (score 0) (*Figure 3.3*). Most respondents (44.3%) provided two correct answers; two was also the median score. Knowledge of ivory-related restrictions (Question 2) had a median score of five. 18.5% correctly knew all seven legal requirements, while 7.4% were either unaware or misunderstood all of these requirements. Legal awareness about the tradable status of ivory (Question 1) varied with gender. Scores for both questions differed between education levels (*Table 3.3*). The level of understanding of each respondent group presented as a ratio between correct and non-correct answers indicated a greater knowledge in male respondents, and more highly educated respondents in general (*Figure 3.4*, see ratios in *Tables S3.1* and *S3.2*).

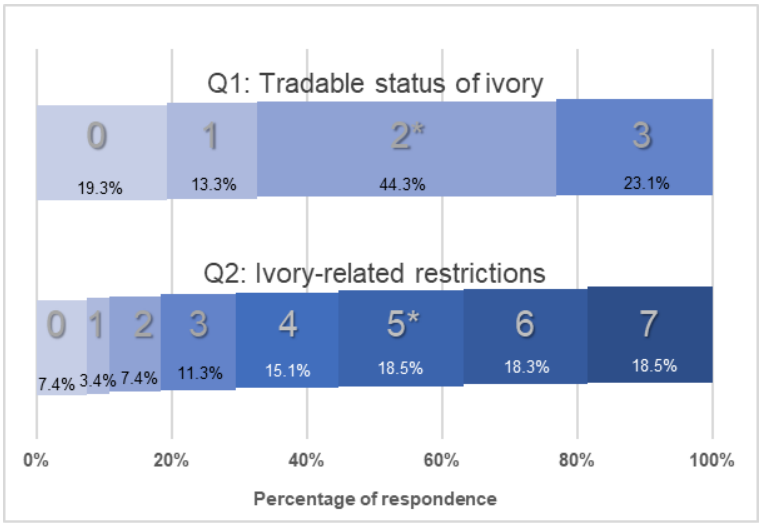


Figure 3.3: The legal knowledge scores of respondents based on number of correct answers. Maximum scores for Question 1 and Question 2 are 3 and 7 respectively. * indicates the median scores for each question. Question 1: Can any of these ivory (African, wild Asian, and domesticated Asian elephants) be legally traded within Thailand? Question 2: Do any of the following activities require an appropriate authorization? Activities included trading ivory as a business, wearing ivory jewellery out of/into Thailand, owning a piece of raw ivory, importing or exporting of ivory out of/into Thailand, trimming tusks from a domesticated elephant, carving/cutting registered ivory, translocating registered ivory.

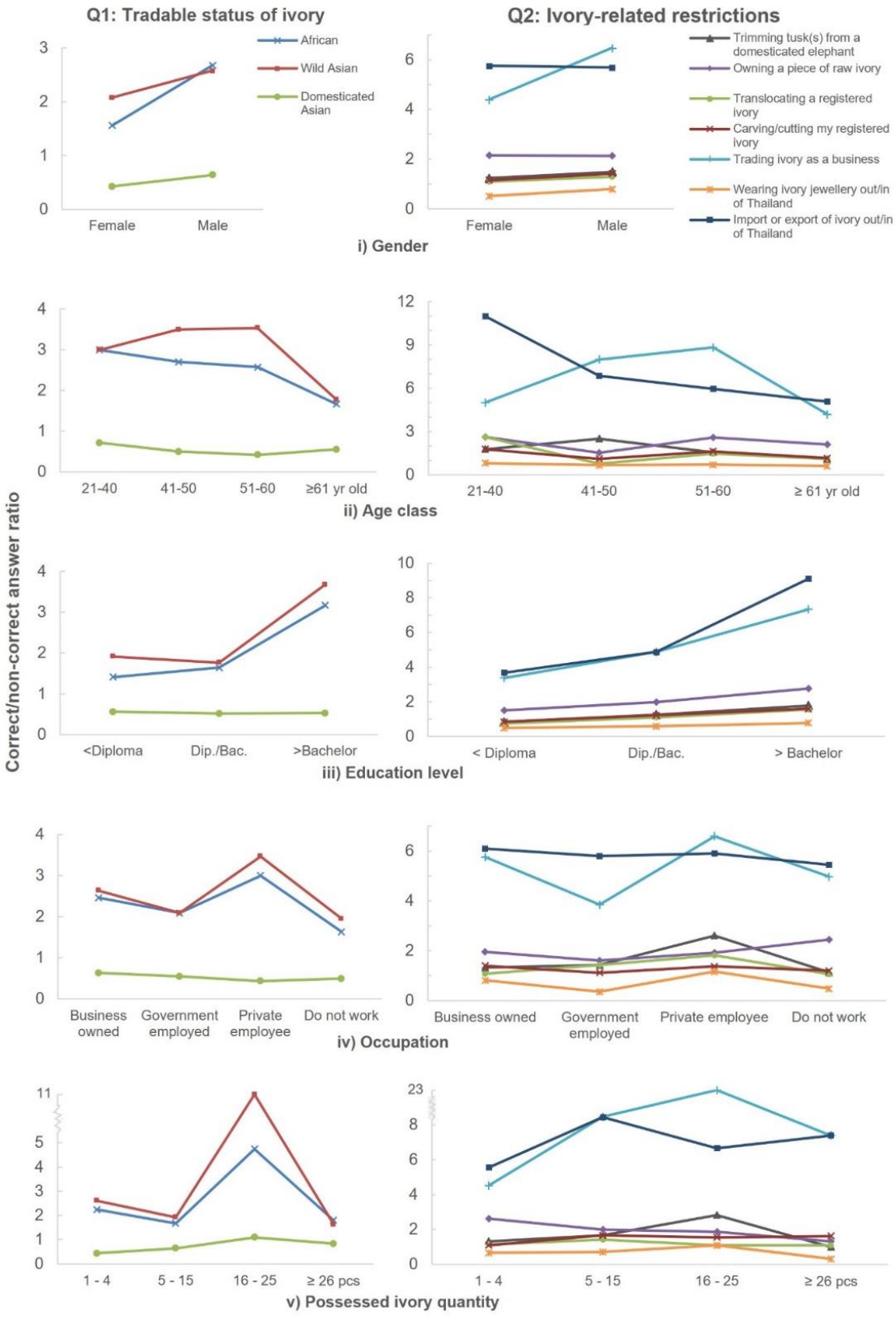


Figure 3.4: Ratios of correct ("correct") and non-correct ("wrong" plus "do not know") responses.*Question 1: Any of these ivory can be legally traded within Thailand?, and Question 2: Any of the following activities required an appropriate authorization?, categorized by i) Gender, ii) Age class, iii) Education level, iv) Occupation, and v) Ivory possession volume. Values on Y axes are ratios between correct and non-correct answers.*

Table 3.3: Significance of the differences between the legal understanding scores and respondents' demographic variables. *Question 1: Can any of these ivory (African, wild Asian, and domesticated Asian elephants) be legally traded within Thailand? Question 2: Do any of the following activities require an appropriate authorization? Activities included trading ivory as a business, wearing ivory jewellery out of/into Thailand, owning a piece of raw ivory, importing or exporting of ivory out of/into Thailand, trimming tusks from a domesticated elephant, carving/cutting registered ivory, translocating registered ivory.*

Demographics		df	Q1 tradable status of ivory		Q2 ivory-related restrictions	
			Value	*p*	Value	*p*
Gender	Female, Male	1	35013.5	**0.006***	33324	0.119
Age class	21 - 40, 41 - 50, 51 - 60, ≥ 61 years old	3	4.541	0.209	5.198	0.158
Education level	< Diploma, Diploma/bachelor, > Bachelor	2	8.063	**0.018***	13.539	**0.001***
Occupation	Business owned, Government employed, Private employee, Do not work	3	4.251	0.236	6.197	0.102
Possessed ivory quantity	1 - 4, 5 - 15, 16 - 25, ≥26 pieces	3	6.226	0.101	3.909	0.271

Almost 70% of respondents knew that trade is prohibited from both African and wild Asian elephants. One-third of participants correctly understood the tradable status of ivory from domesticated Asian elephants (*Figure 3.4*, Q1). Of the seven legal restrictions in Question 2, awareness around the export/import and domestic trade of ivory was highest amongst participants at 85.1% and 84.1%, respectively. In general, more than half of participants knew all the restrictions, except for the "wearing ivory jewellery out/in of Thailand", a restriction which most respondents were either unaware (44.1%) or misunderstood (16.9%) (*Figure 3.4*, Q2).

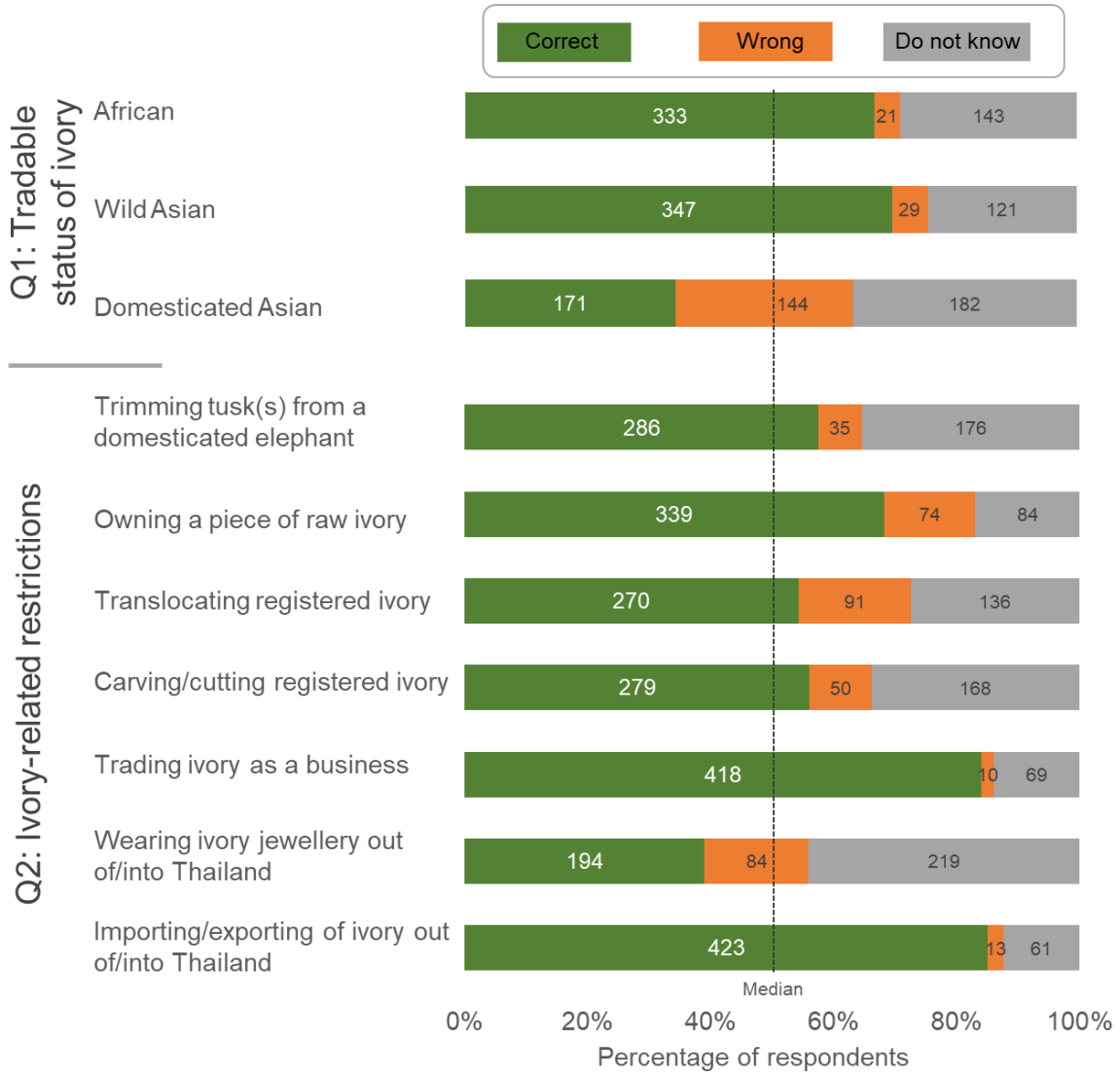


Figure 3.5: The detailed legal understanding of 497 respondents in relation to the tradable status of ivory (Question 1) and ivory-related restrictions (Question 2). *Numbers represent the number of respondents, whose responses were correct, wrong, or "do not know".*

3.3.3.3 Legal compliance using the UCT method

The UCT values ranged between - 0.05 and 0.13 (*Table 3.4*) suggesting that the prevalence of illegal activities was low. These results must be interpreted with caution. The negative prevalence value for List 2 (purchasing) is inconclusive (control > treatment) and all standard error values were high. I explored the estimated proportion of each respondent type to check for design effects for the three lists with positive prevalence values: two of three lists (List 3 and List 4) yielded negative estimates for respondent proportions (*Table 3.5*). Together with the small affirmative response to the sensitive items, these results suggest a violation of the underlying assumptions (age-biased sample) or an extremely small number of respondents undertaking illegal activities, or a combination of both factors. The results were thus inconclusive.

Table 3.4: Legal compliance results using the UCT method. *Pilot and main study results for each of the four UCTs showing list mean, prevalence estimates, standard error (S.E.) and 95% confidence interval. All respondents received the four lists of statements: there are four non-sensitive statements in each list for the control group, while the treatment group received five statements, including a sensitive statement in each list. Prevalence values of illegal activities were the difference in means between the two groups of respondents.*

List	Group	List mean	Prevalence	S.E.	95% CI
1. Illegal possession of ivory product(s)	Control Treatment	1.95 2.04	0.09	0.06	[-0.03, 0.2]
2. Buying ivory from unauthorized selling	Control Treatment	1.74 1.69	-0.05	0.06	[-0.17, 0.07]
3. Illegal trade of ivory	Control Treatment	1.88 2.01	0.13	0.07	[-0.01, 0.27]
4. Ivory smuggling	Control Treatment	1.55 1.57	0.02	0.08	[-0.14, 0.18]

Table 3.5: Estimated proportions of respondent type by total number of affirmative answers responses to control and sensitive statements for the lists. *(Y, Z) where Y is the count of affirmative responses to the control items from 0 to 4, Z = 0 or 1 represented negative or affirmative response to the sensitive item, respectively. Note: The results for List 2 are not presented here because the analysis reported a constant data error of unknown aetiology.*

(Y, Z)	List 1 Illegal possession of ivory product(s)		List 3 Illegal trade of ivory		List 4 Ivory smuggling	
	est.	s.e.	est.	s.e.	est.	s.e.
(0, 1)	0.0000	0.0000	-0.0071	0.0118	-0.0246	0.0220
(1, 1)	0.0289	0.0362	0.0570	0.0409	0.0643	0.0461
(2, 1)	0.0214	0.0328	0.0630	0.0374	-0.0220	0.0288
(3, 1)	0.0230	0.0154	0.0030	0.0111	-0.0015	0.0120
(4, 1)	0.0122	0.0070	0.0122	0.0070	0.0041	0.0041
(0, 0)	0.0000	0.0000	0.0204	0.0090	0.0735	0.0167
(1, 0)	0.1755	0.0243	0.2275	0.0284	0.4246	0.0350
(2, 0)	0.6364	0.0356	0.4614	0.0409	0.3643	0.0383
(3, 0)	0.0970	0.0262	0.1615	0.0267	0.1037	0.0231
(4, 0)	0.0055	0.0113	0.0011	0.0104	0.0137	0.0097

3.4 Discussion

3.4.1 Raising legal awareness of ivory trade actors

Although there is complexity in the relevant legislation as discussed in Chapter 2, overall, actors in the Thai ivory trade chain have a strong understanding of the relevant laws. Nonetheless, different groups of actors vary in their detailed understanding, reflecting the scope and depth of their involvement in various stages of the ivory trade chain. Elephant owners generally aware of regulations pertaining to raw ivory. Ivory traders have considerable legal knowledge of trading activities from sourcing raw ivory, manufacturing it into products, through selling products to ivory consumers. The awareness of ivory consumers is focussed on ivory possession and related activities.

This pattern of differential awareness is also evident in other industries. In an ecotourism study, tourist guides and other groups of individuals involved with tourism and community-based resource management, held a greater knowledge of protected species in Madagascar than did farmers and non-members of forest management associations (Keane

et al., 2011). Similarly, hunters and animal husbandry workers in Mediterranean protected areas are more knowledgeable of species than are tourists (Cortés-Avizanda et al., 2022).

Ivory traders played an important role in educating other actors in the trade chain, presumably as a result of their intermediate position. Trade in ivory involves other actors trusting ivory traders at several points in the chain e.g., elephant owners following their legal advice in selling raw ivory, users buying ivory from a trusted sources such as a familiar shop. Ivory traders are thus important for raising the awareness of other actors in the chain and could be used more effectively by government to increase compliance. Effective intervention to targets could be more effective by use of the right communications medium along with the right message (Challender & MacMillan, 2014).

Different mechanisms are used to disseminate information across actors in the ivory trade chain. All actors access common knowledge about the illegal ivory types and restrictions on international and domestic trading were efficiently accessed via public education campaigns undertaken by the Thai government and conservation organizations since 2014 (CITES SC66 Doc. 29 Annex 8, 2015). The legal knowledge of ivory traders was substantially increased through comprehensive control mechanisms (CITES SC66 Doc. 29 Annex 8, 2015). These mechanisms include training in the regulations and consistent enforcement activities, meaning traders had greater knowledge than the other groups of actors. Elephant owners spread information by word of mouth via their established owner networks. It would be beneficial for government officers, who interact regularly with owners, to use these networks to transfer accurate messages to improve the legal understanding of owners.

To enhance legal understanding, outreach materials need to be presented in language accessible to lay people (van Rooij, 2021) and tailored to particular groups of actors (Kidd et al., 2019). For example, material for Bangkok ivory consumers should be targeted to retired seniors, and highlight information about ivory ownership transfer, along with other knowledge gaps. The level of education of residents in Bangkok is higher than that of people residing in other parts of Thailand (Thailand's Office of the Education Council, 2022) and, therefore, ivory consumers in other areas are expected to have lower levels of legal knowledge than my respondents did. The results of this study should not be interpreted as nationally representative. Future study of the legal knowledge of users at a national level would enable customised communication intervention. Many other studies

have emphasised the need for outreach to be tailored to the literacy level of the audience e.g., bear conservation knowledge held by Lao nationals and Chinese tourists (Davis et al., 2016), wildlife conservation measures in game reserve in Tanzanian local community (Hariohay et al., 2018).

3.4.2 Legal compliance

Questions related to illegal or sensitive activities could potentially lead to inaccurate replies because of participants' concern around the social acceptance and/or legal consequences of their behaviours (Blair et al., 2019; Nuno & St. John, 2015). Direct questioning (DQ) is thus less efficient in protection of privacy of participants, which could result in biased responses. Specialized questioning techniques (SQs) are advantageous because they provide protection, privacy and anonymity of respondents, and reducing response bias caused by social desirability. Nonetheless, such techniques are low in statistical precision and require comprehensive design and implementation to overcome their inherent statistical weakness (Blair et al., 2019; Hinsley et al., 2019; Ibbett, Jones, et al., 2021). UCT and Randomised Response Techniques (RRT) are indirect questioning techniques that have been increasingly used in conservation research (Hinsley et al., 2019). UCT requires a careful selection of statements by the researcher and is easy to use for participants as they have merely to specify the number of statement that apply to them, an approach which enables the researcher to choices in administering the survey including a self-administrated survey (Hinsley et al., 2019). A RRT study needs a randomization device for selecting questions to be answered by participants, as well as comprehensive understanding of the method by the participants. Consequently RRT research has sometimes been conducted in face-to-face to enable the respondents to be supported by the research team (Ibbett, Jones, et al., 2021). As such, the RRT methods requires reasonable resources to be available to the research team.

UCT has been successfully used to estimate the proportion of non-compliance in several conservation studies such as CITES non-compliance in the orchid trade, and wildlife poisoning in pastoral areas (Didarali et al., 2022; Hinsley et al., 2017). My UCT study, however, did not provide clear results, perhaps because of the violation of assumptions inherent to the UCT approach as well as a low level of illegal activities among the non-working age respondents that comprised 60% of my sample. UCT assumes that: 1) the inclusion of sensitive statements has no effect on responses to the control statements; and

2) respondents answering the sensitive item truthfully (Blair et al., 2019; Blair & Imai, 2012). Assumption violations result from careless responses and administrative errors (Blair et al., 2019), as well as a lack of understanding of the UCT procedure (Droitcour et al., 2011) violating the assumption of truthful answers, leading to misleading results (Blair et al., 2019) and contributing to unsuccessful use of the approach (Davis et al., 2019; Ibbett, Keane, et al., 2021). My prevalence estimates were either negative or low with large variance. Negative estimates of prevalence are unrealistic (Nuno et al., 2018), while the small sample sizes would have contributed to the large variances (Droitcour et al., 2011; Hinsley et al., 2019) and low precision (Davis et al., 2019). The statistical limitations of UCT make this technique ineffective for studying populations in which criminal behaviour is rare (Hinsley et al., 2019). My experience illustrates the importance of analysing respondents' demographics to ensure appropriate application of specialized techniques such as UCT. Qualitative methods, such as focus group interviews, are more effective than a SQ for study that the sensitive behaviours are rare and/or limited by a small sample size (Davis et al., 2022; Ibbett, Jones, et al., 2021). Following-up, focus group, interviews would benefit in validating and describing the results obtained from this UCT study.

I did not use any questioning technique other than UCT. Thus I am unable to use another method to evaluate my results (Hinsley et al., 2019). This approach was due to the expected concerns of participants about their privacy and the legal consequences from answering DQ questions as the survey was sent to their physical residence, information which was available as contact detail for target participants, as well as constraint of resource and randomization device for conducting RRT.

3.5 Chapter summary

- Thai ivory laws are complex, as discussed in Chapter 2. Since the 2015 legal reform, the legal knowledge of relevant actors has not been investigated. Understanding the legal awareness of groups of relevant social actors is an initial step towards increasing legal compliance.

- In this chapter, I explored the legal knowledge of key actors in the Thai domestic ivory trade: elephant owners, ivory traders, and ivory consumers using interviews and survey. Results suggest that, in Thailand, elephant traders have greater legal knowledge than elephant owners and ivory consumers. The scope and level of the knowledge of each group of actors were limited by the information accessible to them. Mutual awareness among different group of actors included the illegality of ivory from African and wild Asian elephants, as well as the restrictions around domestic trade and the export and import of ivory.

- I found evidence of ivory traders raising the awareness of the other two groups of actors. Given their position in the middle of the ivory trade chain, traders could be formally used by Thai government to disseminate legal knowledge and distribute educational materials to elephant owners and ivory buyers, taking advantage of their trusted relationship with the other actors.

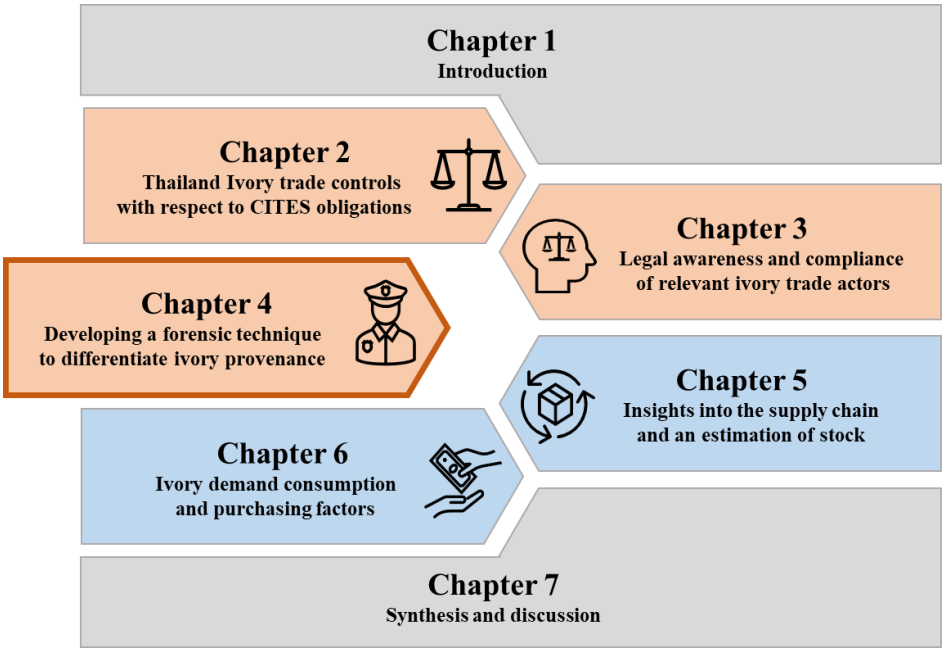
- There are different mechanisms of knowledge raising among actor groups. The awareness of ivory traders is largely a result of enforcement activities, communication among elephant owners effectively works via personal connections, while public education is widely accessible for ivory consumers. Capitalizing on pre-existing mechanisms of knowledge dissemination could improve the knowledge of relevant actors and improve overall compliance.

- Compliance is also affected by the perceptions individuals have of the law. Practical and simpler procedures would make compliance easier, while regular enforcement could discourage rule breaking. My information might be used to inform a strategic plan for public education about the legal requirements imposed by the national laws on the elephant trade in Thailand.

- I also assessed the extent of law breaking by ivory consumers using the Unmatched Count Technique. However, the estimates I obtained are inconclusive, likely as a result of: 1) my study violating the assumptions of the technique and/or 2) the low law breaking of my sample, which was biased towards seniors.

Chapter 4: Developing a forensic technique to differentiate ivory provenance

Identification of the provenance of the ivory is a challenging task for Thai enforcement authorities, particularly as the three ivory types are governed by different laws. In this chapter, I apply the Near Infrared Spectroscopy (NIRS) technique, combined with Partial Least Squares Discriminant Analysis (PLS-DA), to differentiate ivory sourced from African, wild Asian, and domesticated Asian elephants. I hope my findings will support enforcement and trade monitoring to prevent the laundering of illegal ivory, which is a major concern for the legalization of the wildlife trade.



Publication

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4.1 Introduction

As explained in Chapter 2, Thailand permits a domestic trade in ivory from domesticated Asian elephants. This trade must comply with the Elephant Ivory Act, while ivory from both wild Asian elephants and African elephants is prohibited from commercial use. Consequently, given the different legal provision of ivory from these three different sources in Thailand, there is a need for a reliable, non-destructive method to identify the provenance (African, wild Asian, or domesticated Asian elephants) of ivory objects to enable the comprehensive control of the domestic ivory trade in Thailand (Chaitae, Gordon, et al., 2022; Chapter 2). Having such a methodology would ease international pressure to close the trade, an action that would jeopardize the livelihoods of local merchants along the supply chain (see Chapter 5).

An elephant tusk is mainly composed of dentine, surrounded by a thin outer layer of cementum (Baker et al., 2020). The surface of the tip is coated with a layer of enamel. Dentine largely consists of inorganic components embedded in an organic matrix of collagenous proteins (Locke, 2008; Raubenheimer et al., 1998). Hydroxyapatite is the main inorganic component, while major amino acids in the collagen include glycine, proline, and hydroxyproline (Godfrey et al., 2002). The chemical components in ivory are determined by the elephant's physiology and diet, and the environment in which it lives (Prozesky et al., 1995; Raubenheimer et al., 1998; van der Merwe et al., 1990). The vast ranges of Asian and African elephants (Gobush, Edwards, Balfour, et al., 2021; Williams et al., 2020), result in location-specific chemical signatures in ivory reflecting environmental and geographical conditions (Prozesky et al., 1995; Raubenheimer et al., 1998; Singh et al., 2006). The isotope ratios of carbon, nitrogen, hydrogen, sulphur, and oxygen have proved useful for pinpointing the origins of African ivory (Ziegler et al., 2016). Different elemental and amino-acid signatures have also been documented for ivory obtained from different parts of the range of African elephants (Prozesky et al., 1995; Raubenheimer et al., 1998). Asian and African sourced ivory has also been successfully distinguished based on elemental variation (Singh et al., 2006). Whilst these approaches have potential for forensics to support law enforcement, they are destructive and require specialized laboratories and expertise, making them unsuitable for routine inspection or screening (Baker et al., 2020).

Near-Infrared spectroscopy (NIRS) is an approach suitable for examining the composition of intact samples, using the light absorption of chemical bonds within a range of the NIR

spectrum (700-2500 nm) (Osborne, 2006). Prominent NIR absorption in ivory reflects protein (C-H from collagenous protein, N-H from protein residues), and water (O-H) interacting with proteins (Power et al., 2019; Shimoyama et al., 2004). The NIRS technique has successfully distinguished elephant ivory from other ivories, bones and horns (Power et al., 2019; Shimoyama et al., 2004), and documented differences in the NIR absorption of the soft and hard ivories of African elephants (Shimoyama et al., 2004). None of these NIR studies assessed Asian ivory derived from both domesticated and wild populations.

Here, I investigate the potential for the NIRS technique to discriminate between ivory derived from African, wild Asian, and domesticated Asian elephants. As this is an exploratory study, I used three devices developed for the Thai agricultural industry to enable comprehensive spectral coverage from Visible to Long-wave NIR. My study was in response to enquiries from Thai enforcement officers involved in the routine inspection of ivory about the availability of non-destructive, rapid techniques to screen tusks during routine trade monitoring to identify the provenance of the ivory.

4.2 Methods

4.2.1 Samples

Data were collected from 86 samples of raw ivory from 64 elephants as follows:

1) Thirty samples of African elephant ivory (hereafter African ivory), which were cut pieces of confiscated ivory that had been securely stored at the Thai Department of National Parks, Wildlife and Plant Conservation. The exact origins of the African ivory samples were not known. I assumed that each specimen was from a different animal. For the purpose of this study, the African ivory samples referred to ivory originated from all groups of African elephants and considered as single species based on CITES Appendix as discussed in Chapter 1.

2) Thirty samples of wild Asian elephant ivory (hereafter wild Asian ivory), mostly whole tusks, which had been removed from 17 free-living elephants from different protected areas in Thailand. These samples were held by the Department of National Parks, Wildlife and Plant Conservation.
3) Twenty-six samples of domesticated Asian elephant ivory (hereafter domesticated Asian ivory) were tusk tips, and whole tusks with trimmed tips, which had been removed from 17 government-owned elephants. The elephants were raised in captivity, at Lampang province by the Forest Industry Organization, and regularly provided with a diet of agricultural crops (e.g., banana, sugar cane, corn), cultivated grasses (e.g., Bana (hybrid *Pennisetum* spp), Napier (*Pennisetum purpureum*), Pangola (*Digitaria eriantha*), and pelleted food. The animals could also access wild forage such as grass and bamboo.

The ivory samples varied in size, shape (e.g., pieces, complete tusks) and tusk position (e.g., tip, base) (*Figure 4.1*). Additional information such as sex was available for some of the Asian elephant ivory samples, most of which was from male elephants. Due to the uncontrolled nature of the sources of the ivory, I ignored factors relating to the host animals (e.g., sex, age), and the ivory (e.g., storage condition and duration), reflecting the situation facing enforcement officers.

Figure 4.1: Examples of ivory samples varying in size and shape.

4.2.2 Data collection

NIR spectra were collected using three NIRS portable devices that collectively cover the wavelengths between 600 and 1700 nm. All three devices were developed by the Near Infrared Technology Laboratory, Department of Food Engineering, Faculty of Engineering at Kamphaeng Saen, Kasetsart University, Nakhon Pathom, Thailand (*Figure 4.2A*) for use in the agriculture industry. The wavelengths covered by each of the devices follow:

- Device 1 (600 – 1100 nm) at 0.46 nm scanning resolution;
- Device 2 (700 – 1200 nm) at 0.23 nm scanning resolution, and;
- Device 3 (900 – 1700 nm) with scanning resolution of 2.50 nm.

Device 1 and Device 2 collected data in interactance mode; the NIR light penetrates under the scanned surface before reflecting to the device's detector (Pasquini, 2003). For longitudinal positions (see below), therefore, scans of these two devices included data from both cementum and dentine. Whereas the reflectance device, Device 3, sampled the cementum content only. The scans of the cross-sectional cuts for all three devices measured dentine constituents. See *Table S4.1* for the device specifications.

The spectra measurements were taken at positions along and around the sample (longitudinal plane), as well as in the cross-section plane, if possible. Scanning positions avoided areas with notable dirt, cracks and markings. The scanning positions were cleaned with a dry cloth and temporarily marked with tapes to guide positioning. The scans were conducted on a clean area, ensuring that the device's reading probe did not overlap with the markings. The reading probe was placed against a smooth surface in a perpendicular position to prevent external light interference (*Figure 4.2B)*. Each reading area covered 50 mm. diameter. Teflon material was used as a reference before measuring the absolute absorbance of ivory samples. The number of scans per tusk sample varied from 2-9.

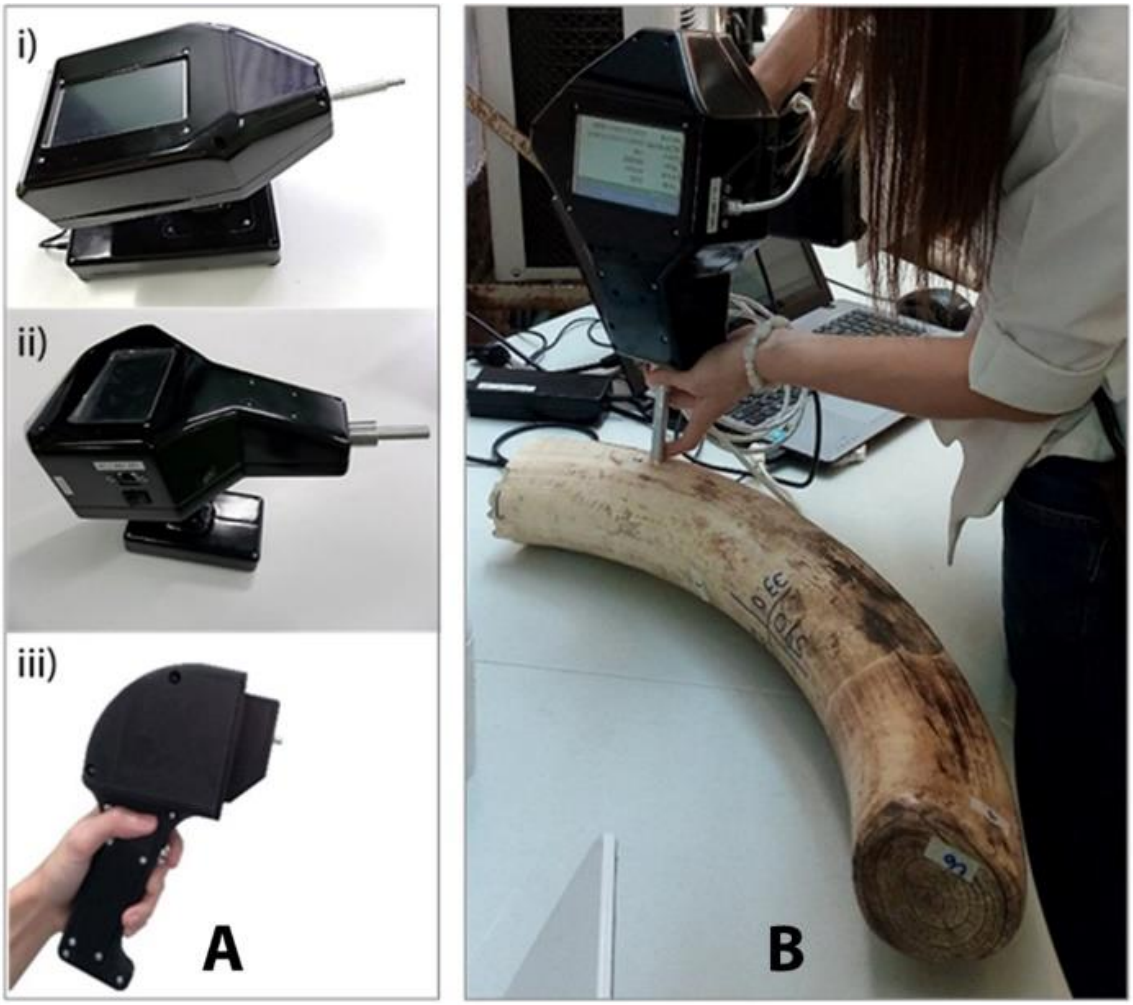


Figure 4.2: Handheld NIR spectrometers*(A): Device 1 (i), Device 2 (ii) and Device 3 (iii) used for making a spectral measurement of an ivory sample (B).*

4.2.3 Analysis

The spectral data were processed and analyzed using Unscrambler 11 software (CAMO, Oslo, Norway). Exploration of the raw spectra was conducted using line plotting and resulted in the removal from the analyses of spectra that were incomplete due to over-absorption. The few scans at tusk tips, which included enamel, were excluded from analysis due to the small sample size. The numbers of spectra from Device 1, Device 2 and Device 3 used in the analyses were 391, 410, and 406, respectively (*Table S4.2*). Analyses were conducted for the longitudinal, and cross-sectional planes (if available) for each device. To prevent pseudo-replication, multiple ivory spectra from each elephant individual were averaged to obtain a single mean spectrum for further analyses, resulting in the following samples sizes for testing:

1) Interspecies classification

The data from the two types of Asian elephant ivory, wild and domesticated, were combined into one group for comparison with the African ivory samples. Across both Asian and African ivory sources, the sample size was 64 in the longitudinal plane, and 43 in the cross-sectional plane.

2) Within species classification

Because few samples of wild Asian ivory were cut in cross-section, only longitudinal scans sourced from Asian ivory, were used for distinguishing between wild and domesticated populations. Across Asian elephant types, the total sample size was 34.

To eliminate noise, mean spectra were processed using a combination of Savitzky-Golay smoothing and derivatives, and standard normal variate (SNV) before further analysis (*Table S4.3*). IBM SPSS Statistics 26 software was used to divide the data into calibration (Training) and validation (Test) sets in a 2:1 ratio. In recognition of the limitations of my small sample size, I undertook ten repeated samplings to generate ten random calibration and validation sets to examine the robustness of the results.

Discrimination models were developed using the Partial Least Squares Discriminant Analysis (PLS-DA). Each spectrum was assigned a dummy variable (ivory type) as a reference value. The model was then developed from the calibration data sets by regressing the spectral data against the assigned reference value. Samples were classified according to ivory type based on non-overlapping cut-off value(s). The correct classification rate (CC) was based on the percentage of non-overlapping samples to the total sample. The PLS-DA results of the ten samplings were similar in both interspecies (longitudinal and cross-sectional planes), and within species classifications. I present CC medians and ranges for the ten samplings (*Table 4.1*) and illustrate the first sampling for the classification results. Details for each sampling are in *Tables S4.4 – S4.6*.

4.3 Results

In each case, only spectra collected from the best performing NIRS device is presented and discussed here. Additional information on differences between the results obtained using three devices are in *Info S4.3*.

4.3.1 Partial Least Squares Discriminant Analysis: Interspecies classification

The correct classification rates ranged from 83-100% for the 10 samplings of the 42 spectra obtained in the longitudinal plane with an overall median value of 96% using Device 3 (*Table 4.1 section 1i*). All 21 of the cross-sectional samples were correctly classified as African or Asian ivory using Device 1 *(Table 4.1 section 1ii)*. See *Tables S4.4* and *S4.5* for the results of each sampling**.**

4.3.1.1 Longitudinal plane samples

Ivory spectra clustered within species with some overlap **(***Figure 4.3A*)**.** NIR light absorbance varied between the two species as noticeable layers in the same wavelength region of the processed spectra (*Figure 4.3B*). Negative peaks of the regression coefficients of the PLS-DA model showed the important variables for classification of the ivory types, including the regions at 1150, 1215, 1385, 1430 and 1585 nm (*Figure 4.3C*).

4.3.1.2 Cross-sectional plane samples

The classification results correspond with the grouping of samples illustrated in the PCA score plot (*Figure 4.4A*). Absorption of NIR light clearly diverges around the 650-830 nm region (*Figure 4.4B*). The discrimination of the ivory species in cross-section scans was influenced by peaks within this region and at 960 nm (*Figure 4.4C*).

4.3.2 Partial Least Squares Discriminant Analysis: Within species classification

In distinguishing between domestic and wild Asian elephant ivory, Device 3 was 100% correct for both the calibration and the validation sets for all ten samplings (*Table 4.1 section 2*). The specific results of the ten repeated samplings are presented in *Table S4.6*.

Separation of ivory sample types were clearly depicted by the PCA score plot (*Figure 4.5A*). Spectra from the ivory from the wild and domesticated Asian elephants were generally similar in the pattern of light absorption, with the appearance of peaks in the same region, but with differences in absorbance intensities (*Figure 4.5B*). The separation between the spectra of the two Asian elephant ivory types was apparent where spectra of each ivory types were close together and formed separate layers (*Figure 4.5B*). The within species classification was significantly influenced by absorption regions at 1405 nm, coupled with variables at 960 and 1550 nm (*Figure 4.5C*).

Table 4.1: PLS-DA results for 1) interspecies classification and 2) within species classification of ivory. *Medians and ranges of correct classification rates (CC) obtained from the ten repeated samplings of the results. Ivory types: Af: African, As: Asian, WAs: wild Asian, DAs: domesticated Asian ivory.*

Ivory source	Calibration			Validation			Total		
	N	CC		N	CC		N	CC	
		Median	Range		Median	Range		Median	Range
1) Interspecies classification									
i) Longitudinal plane (Device 3)									
Af	20	100%	90.00-100%	10	90.00%	60.00-100%	30	96.67%	83.33-100%
As	22	100%	90.91-100%	12	91.67%	58.33-100%	34	95.59%	85.29-100%
Overall	42	100%	92.86-100%	22	90.91%	59.09-100%	64	96.09%	84.38-100%
ii) Cross-sectional plane (Device 1)									
Af	12	100%	100%	7	100%	100%	19	100%	100%
As	9	100%	100%	5	100%	100%	14	100%	100%
Overall	21	100%	100%	12	100%	100%	33	100%	100%
2) Within species classification									
Longitudinal plane (Device 3)									
WAs	11	100%	100%	6	100%	100%	17	100%	100%
DAs	11	100%	100%	6	100%	100%	17	100%	100%
Overall	22	100%	100%	12	100%	100%	34	100%	100%

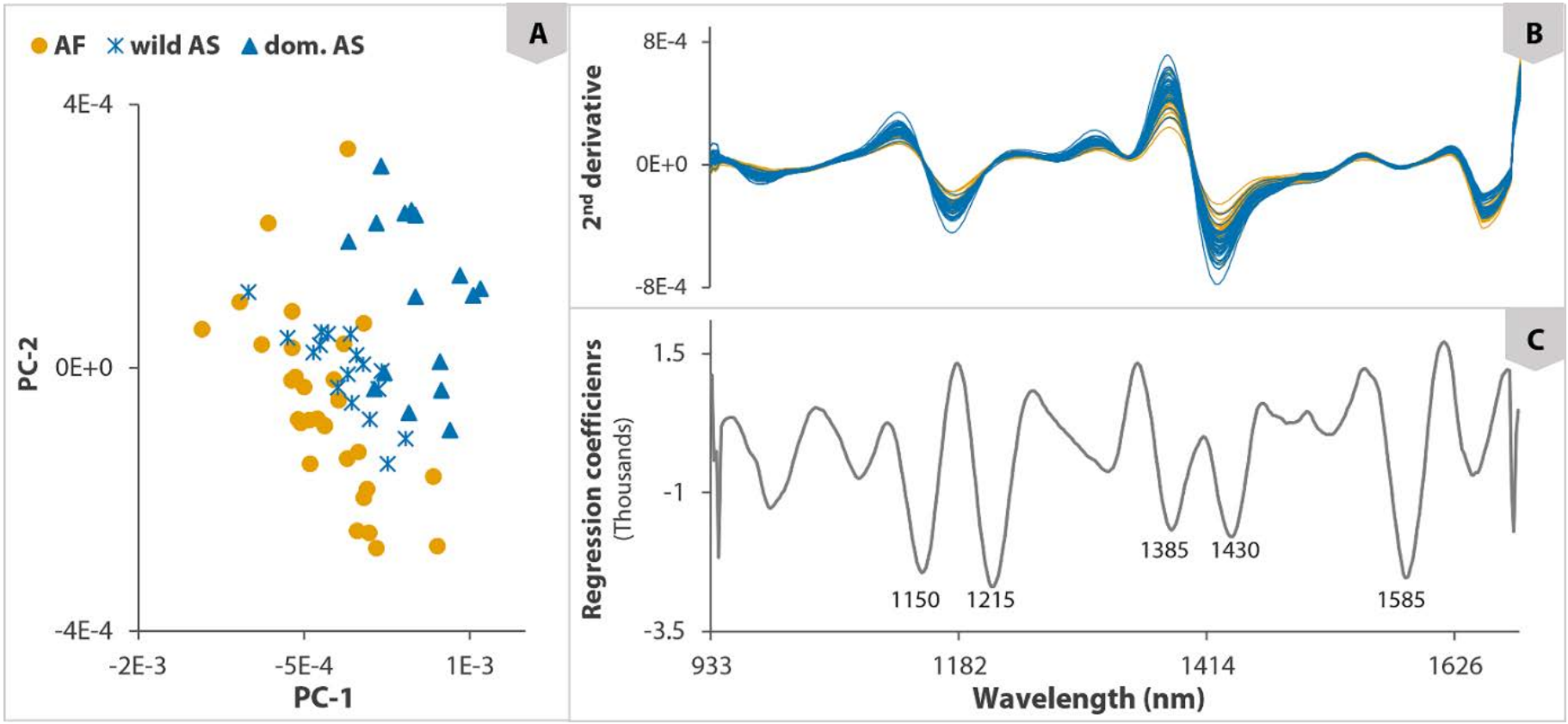


Figure 4.3: PCA score plots for differentiating between African and Asian ivory in the longitudinal plane, processed spectra, and regression coefficients using Device 3. *Orange markers/lines: African ivory, blue markers/lines: Asian ivory. There was no clear separation of data between two ivory species in PCA score plots (A). However, difference in light absorption intensity was apparent in the longitudinal plane spectra (B). The classification of ivory types was largely based on wavelengths 1150, 1215 and 1585 nm (C).*

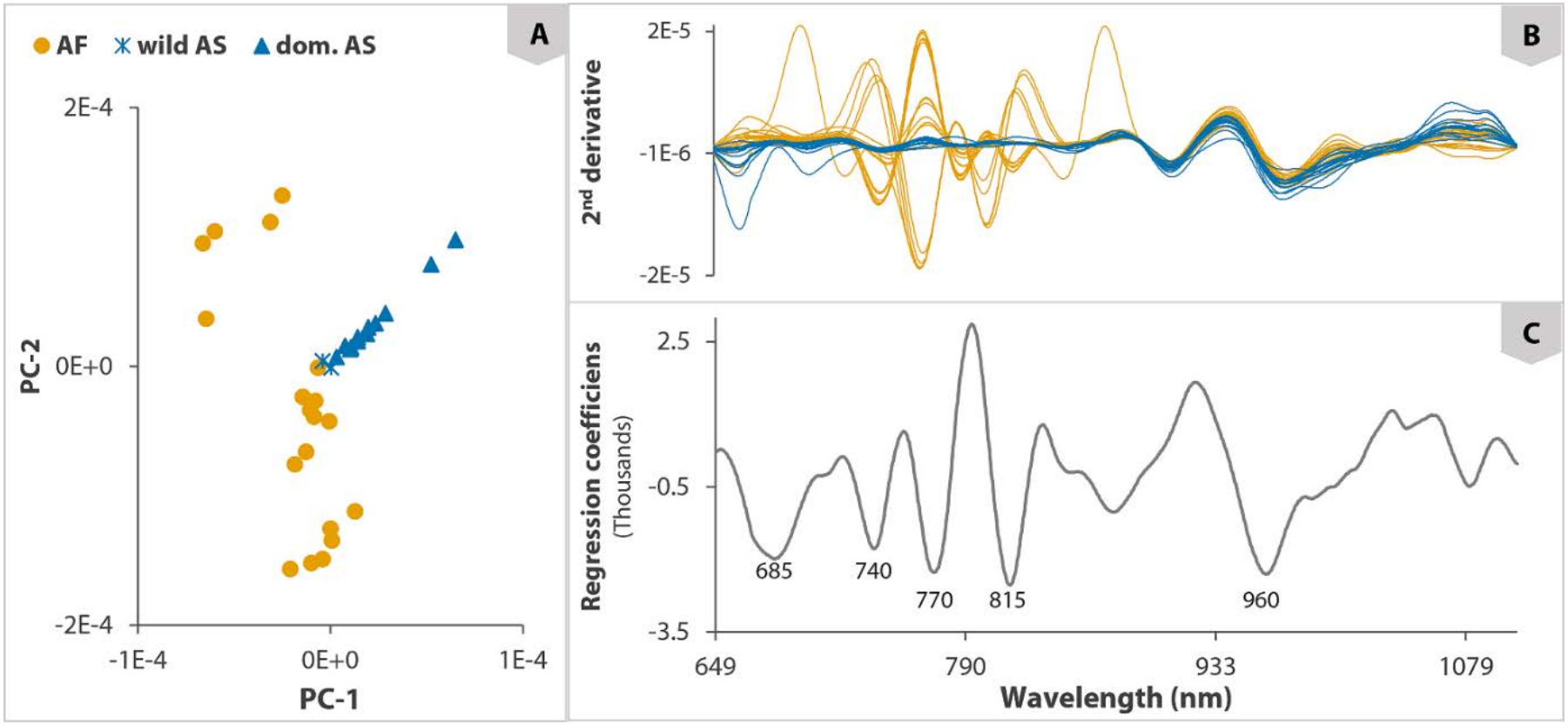


Figure 4.4: PCA score plots for differentiating between African and Asian ivory in cross-sectional plane, processed spectra, and regression coefficients obtained from Device 1. *Orange markers/lines: African ivory, blue markers/lines: Asian ivory. Dentine data were different between two ivory species as presence of the data cluster of Asian ivory in PCA score plots (A). Region 650 - 830 nm included the majority of distinctive spectra with different light absorption (B) and corresponded to the interspecies classifications (C).*

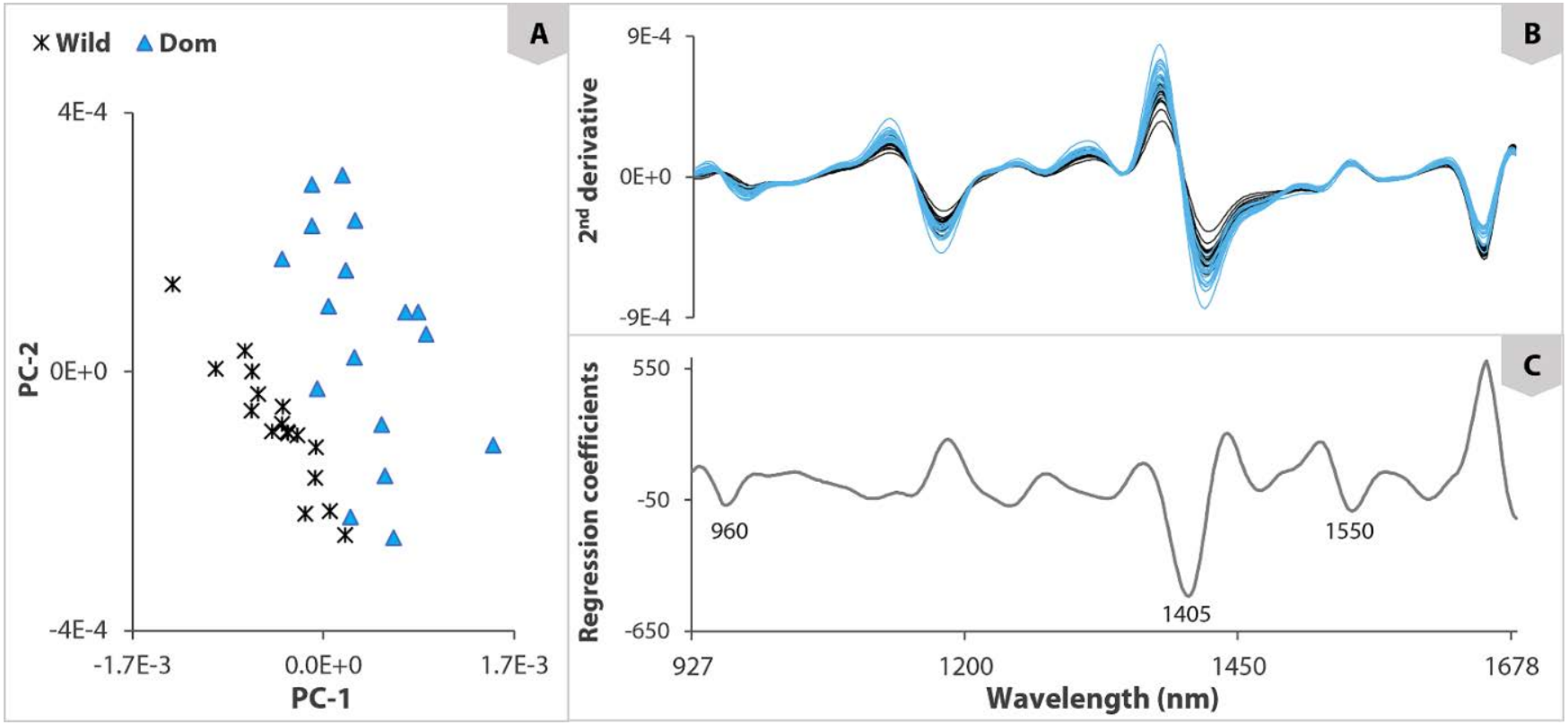


Figure 4.5: PCA score plots for differentiating between wild and domesticated sources of Asian ivory in longitudinal scans, processed spectra and regression coefficients obtained from Device 3.*Black markers/lines: wild Asian ivory, blue markers/lines: domesticated Asian ivory. Separation of the data was noticeable both in the PCA score plot (A) and ivory spectra (B). Within species classification was enabled by differences between the spectra in the absorption regions at 960, 1405 and 1550 nm (C).*

4.3.3 NIR bands of ivory

The PLS-DA classification models were largely determined by wavelengths that diverged in absorbance as negative peaks in the regression coefficients (*Figures 4.3C, 4.4C* and *4.5C*). *Table 4.2* presents the important bands for the discrimination of ivory in my samples.

Table 4.2: NIR wavelength regions for ivory discrimination.

Region (nm)	**Classification** (LP: Longitudinal plane, XP: Cross-sectional plane)	**Absorbing functional group**	**Reference**
685	Interspecies: XP	C-H	(Workman & Weyer, 2008)
740	Interspecies: XP	O-H and C-H C-H	(Shimoyama et al., 2004) (Osborne et al., 1993)
770	Interspecies: XP	O-H	(Osborne et al., 1993)
815	Interspecies: XP	N-H	(Osborne et al., 1993; Stuart, 2004)
960	Interspecies LP, within species: LP	N-H and O-H O-H	(Shimoyama et al., 2004) (Kolmas et al., 2015)
1150	Interspecies: LP	C-H	(Burns & Ciurczak, 1992; Power et al., 2019; Workman & Weyer, 2008)
1215	Interspecies: LP	C-H	(Burns & Ciurczak, 1992; Power et al., 2019)
1385	Interspecies: LP	O-H	(Kolmas et al., 2015)
1405	Within species: LP	O-H	(Kolmas et al., 2015)
1430	Interspecies: LP	N-H O-H	(Vincke et al., 2014) (Kolmas et al., 2015)
1550	Within species: LP	N-H	(Workman & Weyer, 2008)
1585	Interspecies: LP	O-H	(Workman & Weyer, 2008)

4.4 Discussion

4.4.1 Ivory classification using NIR spectroscopy (NIRS)

My findings concurred with the previous studies that indicated the great potential for the NIRS technique as a non-destructive method of compositional analysis for identify the source of the ivory (Power et al., 2019). I was able to use NIRS to discriminate ivory from African and Asian elephants, and demonstrate, for the first time, that the technique can also be used to differentiate between wild and domesticated sources of Asian ivory.

4.4.1.1 Interspecies classification

NIRS discriminated between African and Asian ivory in both planes (*Table 4.1 section 1*). Similar to other studies of ivory using NIRS devices, my scans also showed differences in the NIR spectra in regions influenced by protein and water (Power et al., 2019; Shimoyama et al., 2004). Protein contents in ivory are associated with peaks in the N-H and C-H functional groups. Collagenous protein, the main organic component in ivory, largely comprises glycine, proline and hydroxyproline amino acids (Godfrey et al., 2002). N-H absorption likely represents the presence of these protein residues as they are abundant in ivory (Raubenheimer et al., 1998). In previous studies using NIRS, C-H bonds have been attributed to the chemical constituents of collagen such as CH, CH_2 and CH_3 overtones and stretching of proteins (Power et al., 2019; Shimoyama et al., 2004). Mineralized tissues, including teeth, contain around 10% water per dry weight (Godfrey et al., 2002). In this study, O-H bonds were important for classifying ivory in different wavelength regions, including 740, 960, and 1385 nm. In a study of hydroxyapatite in human teeth, O-H bands involving hydroxyapatite were attributed to water, structural hydroxyl O-H groups and surface P-OH groups (Kolmas et al., 2015).

Like other teeth, tusks mainly comprise inorganic and organic components, but the proportion of these components varies among species and teeth structures. The ratio of inorganic to organic matter in human dentine is about 70:20, excluding water (Dorozhkin & Epple, 2002; Godfrey et al., 2002). The organic fraction is higher in cementum than dentine (D'souza et al., 2020). Both dentine and cementum are richer in collagen, and less mineralized than enamel (Hillson, 1986). Fresh African elephant ivory contained about 65% inorganic matter (Godfrey et al., 2002). An ivory classification study, using Raman

spectroscopy, indicated that the dentine of African ivory has higher mineral content and lower organic component in comparison with Asian ivory (sourced from Thailand) (Edwards et al., 2006). Other authors, using X-Ray Fluorescence to distinguish ivory, reported differences of about 20 elements between the two elephant species e.g., African ivory has higher calcium content, while phosphorus is greater in both Indian and Thai (Nganvongpanit et al., 2015; Singh et al., 2006). Indian ivory also had higher concentration of hafnium and strontium than African ivory (Singh et al., 2006).

Geochemical factors and the availability of food and water contribute to the composition and properties of ivory (Raubenheimer et al., 1998). The brittle tusks of African elephants living in arid areas, where vitamin C is in short supply show low concentrations of amino acids and under-hydroxylation of protein (Raubenheimer et al., 1998). As collagen synthesis requires vitamin C for the hydroxylation of proline and lysine (D'souza et al., 2020), insufficient vitamin C results in under-hydroxylation and likely further decreased strength in the collagen structure (Raubenheimer et al., 1998). Water content also affects the mechanical properties of ivory e.g., elasticity, strength, toughness (Vollrath et al., 2018). It is common knowledge among Asian craftsmen that African ivory, from dry regions, (soft ivory) cracks easily, whilst hard ivory from Asian elephants and African forest elephants is denser and tougher and more suitable for carving (Martin & Stiles, 2003; Walker, 2009).

The origin of my African ivory samples was unknown but assumed to represent the large range of elephants on the African continent, while my samples of Asian ivory were locally sourced in Thailand. This difference is a plausible explanation for the spectra of African ivory being more dispersed in the PCA score plots (*Figures 4.3A* and *4.4A*). The PCA score plots (*Figure 4.3A*) indicate that the differences between the spectra of African ivory and domesticated Asian ivory are greater than those between African ivory and ivory sourced from wild Asian elephants. This similarity of spectral data might be associated with forest African elephants and Asian elephants inhabiting forests in the two continents, which are the sources of the hard ivory. Moreover, free access to diverse food by free-living African and Asian elephants might also minimizes differences in their ivory composition. The spectral differences between domesticated Asian ivory and African ivory were more obvious in the cross-sectional scans in which the Asian ivory was mostly from domesticated sources, (*Figure 4.4A*), resulting in 100% correct classifications for all 10

samplings. Thus, the variation across the range of ivory from African elephants lies outside the signature provided by domesticated Asian elephant ivory, indicating that the NIRS technique is potentially useful for distinguishing the legally-tradable ivory from domestic elephants in Thailand from illegal ivory from African sources.

4.4.1.2 Within species classification

The NIRS device correctly identified the source of each sampled of Asian elephant ivory with 100% accuracy (*Table 4.1 section 2***)**. The variation in the cementum spectra contained useful information for the classification of the two types of Asian elephant ivory (*Figure 4.5A*). The important contents responsible for classifying two Asian ivory were water (O-H) and protein residues (N-H) (*Table 4.2*).

Domesticated elephants were transferred into the tourism industry after the 1989 logging ban in Thailand, and now have less opportunity to forage on their natural diet (Godfrey & Kongmuang, 2009; Phuangkum et al., 2005). Thai domesticated elephants regularly feed on agricultural crops, non-native cultivated grasses, and pelleted food plus pineapple plants common in elephant camps in different parts of Thailand. These crops also increase exposure to agricultural chemicals (Phuangkum et al., 2005). In contrast, free-ranging Asian elephants forage on hundreds of different plant species across forest types and seasons; for example, at least 260 plant species of browse and grass plants are consumed by elephants in Thailand's Huai Kha Khaeng Wildlife Sanctuary (Sukmasuang, 2003). Thus, there is diet overlap between the wild and domesticated elephants. Wild elephants have been observed feeding on crops bordering their natural habitats in Thailand Vinitpornsawan et al., 2016; van de Water & Matteson, 2018; Pla-Ard et al., 2020), while domesticated elephants may occasionally access to natural forage. This overlap in forage is likely to be reflected in the NIR spectra from the two ivory types.

Studies of carbon isotopes in elephant tooth enamel indicate that browse plants dominate the diet of wild elephants today (Cerling et al., 1999). Like Indian elephants (Joshi & Singh, 2008), wild elephants in Thailand spend larger amounts of time browsing than grazing (Sukmasuang, 2003). The protein content of browse plants is higher than grasses, and can contribute about 70% of organic carbon for bone collagen synthesis in Asian elephants (Sukumar, 2003; Sukumar & Ramesh, 1995). The food provided to two domesticated populations of Thai elephants was low in protein and calcium (Romain et al.,

2014). These elephants mainly obtained protein from Bana grass, corn cobs, and pellets. Calcium is the most abundance mineral in ivory (Nganvongpanit et al., 2015; Raubenheimer et al., 1998) and is part of hydroxyapatite crystals that account for the rigidity of the tusk (Vollrath et al., 2018). Tusk material is largely composed of dentine, the main component of ivory products (Baker et al., 2020). Further NIRS work on dentine will be beneficial for identifying products of Asian ivory.

4.4.2 Application of NIRS technique for ivory trade control

Reliable identification of the source of ivory has been an important challenge facing enforcement officers, particularly for in-field tasks (Baker et al., 2020). In circumstances such as those found in Thailand, where the legal domestic trade is only allowed for ivory derived from domesticated Asian elephants, ivory identification is challenging and important. Ivory investigations include screening and routine inspections, which need to be conducted in a non-destructive manner. A portable identification tool, like that used in the analysis presented here, has the potential to facilitate in-field investigations by enforcement officers. Moreover, separate analyses between longitudinal and cross-sectional spectra from tusks would improve discrimination between major ivory forms; i.e., use of longitudinal discrimination for whole tusk, applying cross-sectional analysis for identifying ivory products.

The NIRS technique is already widely used by the agro-food industry and pharmaceutical industries (Osborne, 2006; Workman & Weyer, 2008). A portable NIR spectrometer costs less than the equipment and chemicals used in conventional analyses. Commercial handheld NIR spectrometers can be manufactured at low cost, and are easy for non-specialists to use (Beć et al., 2020; Vance et al., 2016). The locally built NIRS devices I used cost around USD5,000 for each of these prototype models. I applied available NIRS devices varying in specifications (e.g., measuring mode, resolution, wavelength) to expand coverage of my exploratory study. My results can inform the customization of an NIR spectrometer for ivory discrimination. The rapid and reliable results I obtained fulfil the needs of enforcement officers, particularly for routine inspection or initial screening. The modest cost of this approach should facilitate their accessibility for existing regional wildlife enforcement units in Thailand. Availability of commercial devices could further enable use in wider enforcement communities.

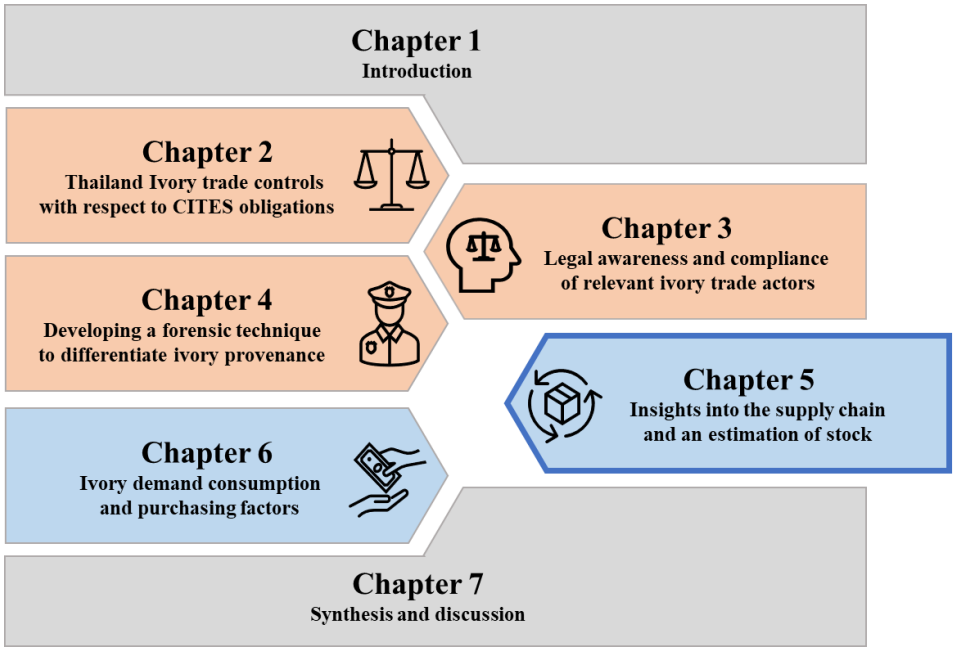
It is important to note that my findings are based on local samples of Asian elephant ivory in Thailand. The application for other uses and in other countries needs to be done with caution as different geological and environmental conditions influence ivory composition. Complete characterization of spectra peaks needs comprehensive attention in relation to the chemical aspect because of the broad overlapping appearance of spectra in the NIR region (Stuart, 2004).

4.5 Chapter summary

- A significant source of concern over the legalization of ivory trade involves legal ivory market masking the laundering of the illegal supply. Thailand's situation is particularly contentious because of the different legal status of different types of elephant ivory. Thai law allows the local sale of ivory from domesticated Asian elephants, which creates challenges for Thai enforcement officers in identification of ivory provenance.
- I investigated the capacity of non-destructive Near Infrared (NIR) spectroscopy (600 -1700 nm), combined with Partial Least Squares Discriminant Analysis (PLS-DA), to discriminate between ivory from African, wild Asian and domesticated Asian elephants. This study clearly established the potential of NIRS to discriminate between both: (i) Asian and African ivory, and (ii) wild versus domesticated Asian ivory. Also, separate longitudinal and cross-sectional analyses improve discrimination between major ivory forms.
- NIRS technology is very simple to use in the field, and has the potential for enforcement officers using portable NIR spectrometers undertaken timely and cost-efficient identification of ivory. Equipping enforcement officers with such devices should enable efficient and effective screening and routine inspection of ivory in the field.
- Implementation of this technique, particularly for confiscation and prosecution, will require further research to capture the variation in ivory among elephants with diverse feeding regimes and the development of a customized device. This advance would enable the effective implementation of the Thai laws designed to enable the sustainable use of ivory derived from the routine management of domesticated Asian elephants.

Chapter 5: Insights into the ivory supply chain and an estimation of stock

The first part of my study on market interactions involved an exploration of the supply-side. I interviewed elephant owners and ivory manufacturers to understand the legal supply chain mechanism and relevant factors influencing the local supply from Thai domesticated elephants. I also quantify annual supply obtained from Thai domesticated elephants based on relevant government records.



Publication

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5.1 Introduction

The international trade in wildlife parts and products is of significant conservation concern. The global demand for ivory, for example, is considered to be a significant threat to African elephant populations (*Loxodonta* spp.) as elaborated in Chapter 2. Such trade involves multiple actors at different levels of the supply chain. The illegal ivory trade involves a complex supply chain that includes elephant poachers in African countries, organised operations of local and national dealers to ship the raw materials, and consumers across multiple continents (Underwood et al., 2013; UNODC, 2020b). These supply chain actors constitute a sophisticated network that ultimately facilitates, and perhaps drives, the operation of the illegal trade.

Both simple and complex relationships between supply chain actors also exist in the legal, domestic supply of wildlife parts and products. Supply chains in the bushmeat trade vary between animal species and contexts (Cowlishaw et al., 2005). These chains can begin with either commercial operators or farmer/hunters, before moving through a network of traders to consumers (Cowlishaw et al., 2005). Alternatively, the supply chain can be relatively simple with non-commercial hunters sourcing bushmeat for subsistence or local consumption (Cowlishaw et al., 2005; Delisle et al., 2018). Non-destructive consumption, such as in the vicuna (*Vicuna vicuna*) luxury wool trade, can involve relationships between communities and herders, national and international manufacturers, exporters and traders (Kasterine & Lichtenstein, 2018). These types of legal trades in animal products can bring significant incomes to local communities, maintain traditional practices and values, as well as being of conservation benefit (Gordon, 2008).

Thai ivory market is dependent on the supply from local domesticated elephants only. Knowledge of ivory supply is critical to evaluating the feasibility of a long-term legal market in Thailand. This chapter consists of two sections. In the first section, I map the domestic, legal ivory supply chain, and conduct a supply chain analysis to explore factors influencing ivory supply. I quantify the annual supply of raw ivory produced by Thai domesticated elephants in the section second section.

5.2 Methods

5.2.1 Domestic, legal ivory supply chain

5.2.1.1 Data collection

Data were collected via 32 face-to-face semi-structured interviews and two telephone interviews with 23 elephant owners, and 11 ivory manufacturers. My questions for the elephant owners were around decisions in tusk harvesting and uses e.g., how, and why tusks or parts thereof (hereafter tusks) of elephants were taken, how the tusks were used, and why and how they were sold. The ivory manufacturers were asked about tusk supply: their sources of raw tusks and how they were sourced. See details of interviews in *Info S3.1*. The interviews were conducted in Thai to facilitate understanding of the interviewees and their responses. The data were collected between November 2019 and February 2020 in different provinces in the North, Northeast, and South regions of Thailand (See locations in *Figure 3.2*).

Participants were chosen using purposive and snowball sampling. The interviews began in the two main ivory manufacturing hotspots: Nakhon Sawan and Uthai Thani in the North, and Surin in the Northeast, based on my pre-existing contacts. Additional elephant owner interviewees were referred by the interviewed participants, as well as local officers of the Department of National Parks, Wildlife and Plant Conservation (DNP), and Department of Livestock Development (DLD). The interviews of elephant owners were carried out among groups of elephant owners living in the South, North and Northeast to cover variation among regions (see *Table 3.1* for area description). All participants gave verbal consent to be anonymously interviewed and audio recorded, as approved by the James Cook University Human Ethics Committee (H7873). Verbal consent was obtained due to a combination of poor literacy of potential participants, and potential hesitancy associated with the signing of documents. The interviews continued until data saturation was reached.

5.2.1.2 Analysis

All transcription were conducted in Thai to preserve the contextual meanings and perspectives of the interviewees. Quotations that are part of the Results are presented here in English. The translation of these quotations represents the meaning expressed by the participants for research validity (van Nes et al., 2010). Description and language amendments were put in square brackets to facilitate reading. Coding was conducted in English using NVivo (QSR International Pty Ltd., 2018). I conducted open coding to enable a regeneration of concepts and category to refine the legal supply chain map and analysis of the supply chain.

Supply chain mapping

At the beginning of the study, I created a simple supply chain composed of three stages: source, manufacturing, and consumption, to guide data collection. To allow a more comprehensive understanding of the Thai ivory trade, I refined the supply chain using data from interviews with elephant owners and ivory manufactures, drawing on elements of grounded theory (Corbin & Strauss, 2015). Grounded theory uses empirical data to generate concepts and construct theories, thereby permitting interpretation and themes to be discovered within the data. As I focused on supply side information, the discussion in this study relates to the connections between elephant owners and ivory product manufacturers.

Supply chain analysis

As I employed open coding, different parts of each transcription were coded and marked with appropriate labels for identification during analysis (codes). The codes were grouped under the same category based on relationship and similarity. I created a conceptual model describing the process and drivers of ivory supply based on all categories and their relationships.

Coding began with groups of elephant owners to set up initial concepts/categories based on their perceptions as supply sources. I later coded the data from ivory manufacturers and combined the codings of ivory manufacturers to those of the elephant owners. This integration allowed data matching, and connected links between the two stakeholder

groups. After generating an initial conceptual model, codes were then reworked to refine and validate the model.

5.2.2 Annual ivory supply from domesticated elephants

Data about raw ivory were extracted from three sources for the period 22 April 2015 (pre-existing ivory traders must apply for trade permit within 90 days after the Elephant Ivory Act B.E. 2558 (2015) coming into effect 22 January 2015) – 31 December 2019:

- Acquisition records of raw ivory reported by ivory traders under Elephant Ivory Act 2015 obtained from DNP. The data were drawn from eighteen ivory traders who involved in manufacturing ivory products in two hotspots: Surin province of Northeast, and Nakhon Sawan and Uthai Thani provinces of North. These records represented commercially-held stocks.
- Certificate of ivory origin issued by local registrars of Department of Provincial Administration with notifying either changes of domesticated elephants' physical characteristics or death of domesticated elephant under the Draught Animals Act 1939.
- Inter-provincial movement permits under the Animal Epidemics Act B.E. 2558 (2015). The permits have been issued by DLD for regulating transporting raw ivory across provinces.

Data were extracted from hard copies in Thailand during May 2020 - June 2021. The data from three sources have been matched by relevant information, including quantity and weight ivory, identification number, timing of activity, source and destination of ivory. Unmatched data were included into the dataset to complete missing records. Constraints imposed by the COVID 19 pandemic prevented international travel and full validation of the raw data. I used validated records for estimates, therefore these estimated numbers represent minimum volumes. Weight was shown in Kilograms (kg.)

5.3 Results

5.3.1 Thai ivory supply chain map

Figure 5.1 illustrates the supply chain of the Thai ivory trade, presented as supply chain actors engaged in the trade. The chain consists of activities of five key groups of supply chain actors: elephant owners, intermediaries, ivory product manufacturers, product retailers, and ivory consumers. Interaction of the main actors within the chain is illustrated in *Table 5.1*. Raw tusks enter the chain by direct transaction involving the elephant owners or via an intermediary. Some tusks are purchased by users without the manufacturing step. These tusks are generally pairs of complete tusks, which are mostly used for decorative purposes.

Ivory manufacturers preferred to source ivory directly from elephant owners rather than from ivory possessors because of concerns about the certification of sources and ivory quality.

> *I choose to buy ivory recently cut or removed from elephants as I am quite sure this ivory are from domesticated elephants and have documents [certificate of ivory origin, movement permit etc]. That will not give me [legal] trouble. Also, old ivory is, sometimes, not good for making products…too dry and crack.* [TM17, Nakhon Sawan]

Ivory products, such as jewellery or sacred items, are manufactured in two main areas: Surin in the Northeast, and Nakhon Sawan and Uthai Thani in the North. Manufacturers in Surin source tusks from Surin-based elephants that are either living locally or working in other areas. Raw tusks sourced from the South and the North have lower prices than from Surin. Tusks from Southern owners are mainly sold to Surin manufacturers; some are supplied to manufacturers in Nakhon Sawan. Tusks from Northern elephants mainly go to within-region manufacturers i.e., in Uthai Thani and Nakhon Sawan. Flows of tusks to manufacturers occur mainly through networks of elephant owners and prior contacts that elephant owners establish during their travels as illustrated by the following quote:

> *I brought my elephants to wander in different provinces [earning money from getting people to pay for the food of the elephant] when it was not prohibited. [From these travels] I [then] know many people. I sometimes gave my phone number to them. They can reach me when it is needed [regarding the sale of elephants or tusks]. Also, there are networks of elephant owners who dispersedly work at [elephant] camps around the country.* [EO14, Surin]

Intermediaries are important supply chain actors for the trade of raw ivory, particularly in connecting sources with buyers from outside the area. Locals, either traders or (ex) elephant owners, take advantage of their knowledge of ivory availability within the area to gain extra income through facilitating ivory trades.

> *I bought tusks from either the South, Northeast or North. I myself do not know many elephant owners, but there are middlemen who know where elephant tusks will be cut. They are Surin locals who connect buyers with elephant owners. Surin elephant owners work countrywide. Elephants working or doing shows in the South are also from Surin. They are connected easily today using [social media platforms] Line and Facebook.* [TM9, Nakhon Sawan]

Ivory manufacturers sell finished products to retailers countrywide. There are also transactions of both raw ivory and finished products between manufacturers in two regions. Northern manufacturers are known to be skilled at making elaborate carvings, while Northeast producers are considered capable in making products for the mass market. Manufacturing may involve work carried by freelance carvers and traditional jewellers. Domestic users purchase ivory items from manufacturers' and retailers' shops. Manufacturers also obtain raw ivory owned by processors or ivory consumers.

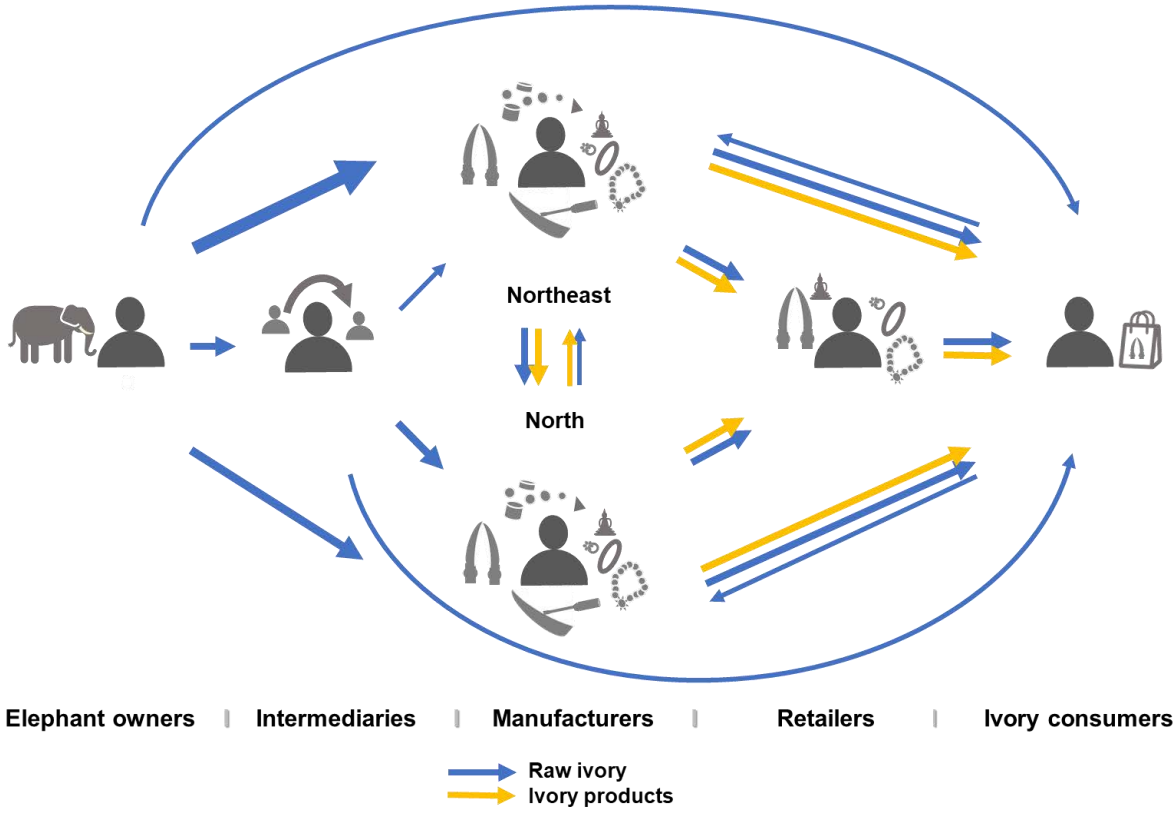


Figure 5.1: The supply chain of the Thai ivory trade involves five supply chain actors. *Tusks harvested by elephant owners are passed to manufacturers either via direct trade between elephant owners and ivory manufacturers or via intermediaries, who are particularly important for manufacturers without access of local ivory e.g., Nakhon Sawan and Uthai Thani of the North. Finished ivory products are passed along the chain to final users through networks of manufacturers and product retailers. While the flow of ivory from sources to users mostly involves monetary transactions, some elephant owners may transfer ivory to relatives and friends for in-kind and sentimental purposes. The width of the arrows represents the proportional volume of activities.*

Table 5.1: Main supply chain actors and their interactions in the supply chain of Thai ivory trade.

Supply chain actors	Descriptions
Elephant owners	Owners of the elephants either keep elephant themselves or pay mahouts (keepers) to take care of the animals. Elephant owners from a 'mahout family' tend to domesticate elephant themselves and earn significant income from elephant uses (e.g., hiring for tours and shows) and elephant keeping. In my sample, this group of elephant owners generally own fewer than 5 elephants. The group of owners having up to more than 20 elephants primarily pays mahouts to take care of their elephants. These elephants either work for family-owned elephant tourist businesses, locally known as elephant camps, or are hired for work in the tourist businesses countrywide.
Manufacturers	Manufacturers make finished ivory items from raw tusks. Manufacturing varies from polishing the tusks and preparing bases for a decorative tusk pair, through to elaborate carvings. The main sites for manufacturing ivory products are: Nakhon Sawan and Uthai Thani, two adjacent provinces, in the North, and Surin in the Northeast. Commercial carving began in the Northern provinces around 90 years ago with ivory supplied from other areas, including Surin. Surin was initially a source of supply as well as producing small amounts of plain sacred ivory items (e.g., Buddha amulets). Over the last two decades, villagers obtained knowledge of fine carving from the North, coupled with Thai government promotion of local crafts to increase the income of residents. Surin ivory business have thus become a major manufacturing site. Ivory manufacturers sell ivory items both wholesale to other traders and retail to end users.
Intermediaries	Intermediaries are locals in areas with elephants. Some elephant owners take this role to seek supply for manufacturers who previously bought their own tusks. Some intermediaries are ivory traders and former elephant owners. Buyers, including manufacturers, tend to stick with a specific, trusted intermediary.
Retailers	Retailers occur in different provinces. They are mostly small family businesses without employees. They tend to trade in ivory in addition to their other businesses or occupations. Ivory is sold amongst other merchandise in their shops, including jewellery and souvenirs made from other materials e.g., bones of cattle and ostrich, wood, gold, silver. Ivory retailers sell ivory either at their residences or in rented stalls/shops. Most Surin retailers operate small shops at the Elephant Study Centre in Ta-Klang and are closely related e.g., siblings, relatives.
Ivory consumers	Ivory consumers include possessors of ivory, either in the form of raw tusks or finished products. They have acquired ivory through means including purchase, gifting or inheritance.

5.3.2 Supply chain analysis of Thai ivory trade

I found three steps in the decision making of elephant owners regarding selling ivory: tusk harvesting, tusk use and sale destination (*Figure 5.2*). I discuss the influences on decision making at each stage of the supply chain in the following sections. In summary, ivory supply is significantly influenced by the financial needs of elephant owners and market factors. Elephant use and management, sentimental values, ivory beliefs, tusk forms, and legal awareness are secondary factors affecting decisions relating to the flow of ivory from elephant owners.

1) Tusk harvesting: a common practice in elephant domestication

To understand the start of the supply chain, I asked elephant owners how the tusks were sourced from elephants (Section 1 of *Figure 5.2*). Elephant owners cited two forms of ivory obtained from domesticated elephants: cut pieces and whole tusks, the choice of which is associated with elephant management practices and the financial needs of elephant owners.

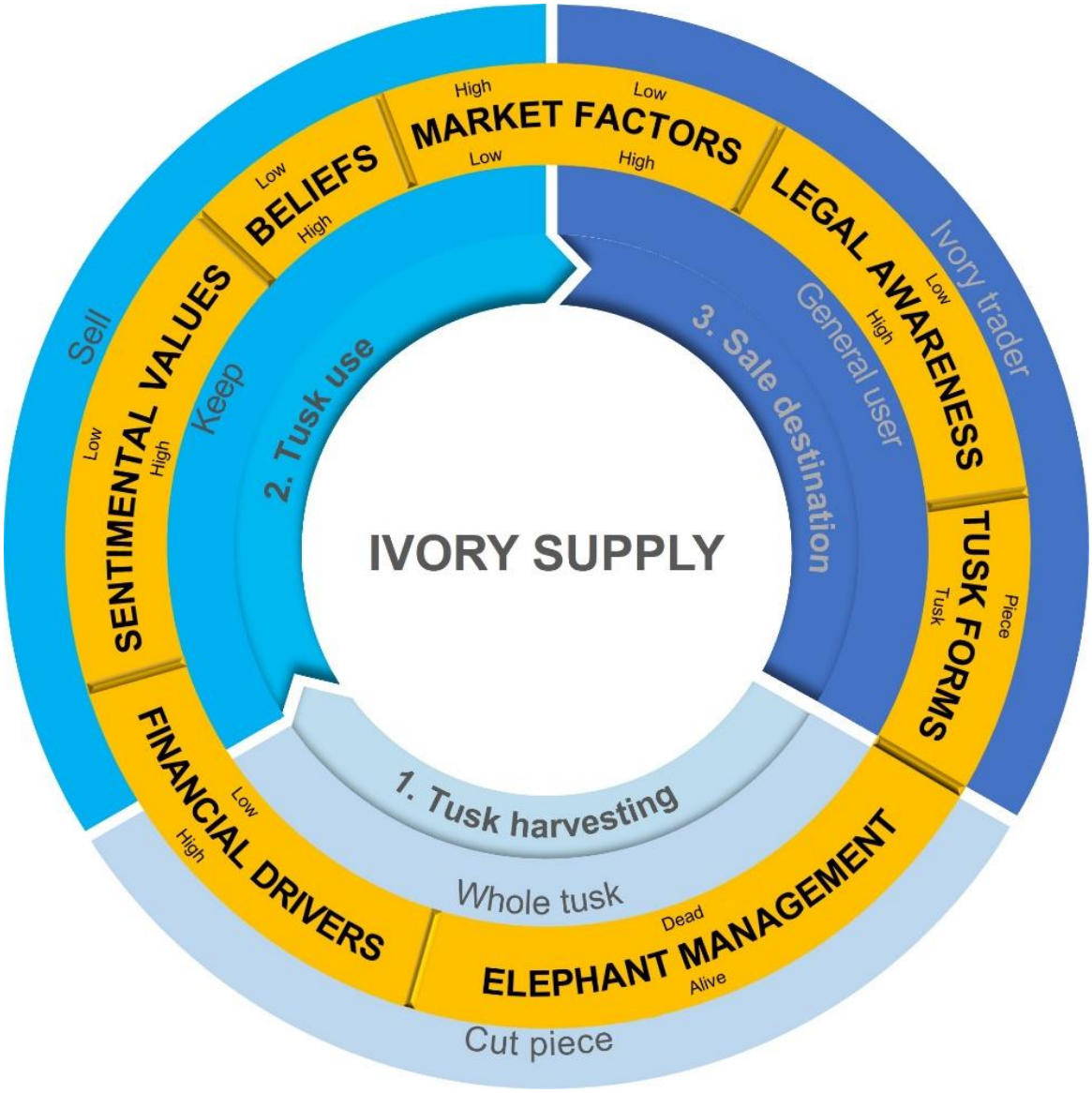


Figure 5.2: Elephant owners' decision making and factors influencing ivory supply for manufacturing.*Ivory supply from elephant owners in Thailand is driven by multiple factors at each step. The financial needs of elephant owners have a strong effect on decisions related to tusk harvesting and use. Tusk use and sale destination are influenced by market factors (price and access). Other influences on ivory supply include elephant use and management, sentimental values, ivory beliefs, legal awareness and tusk forms.*

Elephant management. Whole tusks are removed from dead animals. In contrast, pieces of tusk are cut or trimmed throughout the lifespan of male elephants. All elephant owners emphasized that cutting tusks causes no harm to the elephants as illustrated by this response by a Surin elephant owner:

> *We cut tusks of the elephants at one-third of the length protruding out of the lip; this will not hurt animals. Cutting period cannot be fixed, [it] depends on tusk growth. Tusks grow about 3 - 10 cm a year. The growth rates are different among tusk types. Hin [stone] tusks grow slower than Yuak [banana trunk] and Wai [rattan] tusks. My 50 year-old elephant has Yuak tusks, which are now about 180 cm in length. I cut his tusks 4 times. I got about 80 cm pieces for the first cut, and later 50 - 60 cm pieces for each cut about every 5 - 6 years. No drug is needed during cutting, mahout controls the elephant while an elephant shaman cuts tusks. Only when the elephant dies, we get the whole tusks.* [EO4, Surin]

While a plan related to the whole tusks is needed only once the elephant dies, cutting throughout an elephant's lifespan requires numerous decisions. As noted by an elephant owner:

> *A tusker without tusk cutting will earn more money from parading and show[ing their elephants] than if those tusks were cut because it looks much better [more powerful]. Elephant owners must choose to keep long tusks or cut tusks [for sale] to pay for necessities.* [EO6, Surin]

All groups of elephant owners refer to cutting or trimming the tusks of domesticated elephants as a long-established practice, which is necessary and commonly practised. They also mentioned that elephants were not kept solely for the purpose of tusk supply:

> *I keep elephants because I love them, and no one keeps them for taking their tusks only. It is an extra [by-product] from having a tusker.* [EO7, Surin]

Surin elephant owners cut elephant tusks for elephant healthcare and safety, as well as to prevent the risk of injury to people who get too close to elephants. Trimming is normally not done on a regular schedule; rather, it is dependent on the growth of tusks and their maintenance needs (e.g., as a result of a tusk breaking):

> *[Tusk cutting] is [the main source of] livelihood for elephant keeping. We cannot avoid cutting if tusks are too long. Very long tusk elephants have difficulty in living, and it is dangerous for the surrounding people, and other elephants. Long tusks are heavy too. Elephants with crossed tusks cannot use their trunk well. Tusks also are worn out around trunk moving positions. Tusks grow continuously like nails. So if we don't cut deep, there is not a problem. But the cuts that reach elephants' tusk nerves causes infection. Cuttings, then, must be away from the nerve. After cutting, elephants feed better. Cuts in young males will increase the size of tusk bases. All do this, the first cut was done since the males are less than five-years old, depending on the rate of tusk growth which differ among individuals. If a tusk was broken, we mostly cut both tusks to make an equal size and [so it] looks good.* [EO2, Surin]

Besides the group of elephants belonging to Surin owners, there are elephants previously used in forest logging, before the 1989 logging ban, particularly in the North and South regions. The ex-logging elephants mostly work in elephant camps in tourism areas of the North and South regions. Some also are used as labour in logging operations in either rubber plantations or government forest plantations. The practice of cutting the tusks of labouring elephants is related to maintaining their working competence:

> *Southern males are still being used in logging, mostly in rubber plantations, not in the forests like before. Long-tusk elephants cannot work well and the tusks impede movement. Logging works involve lifting tree logs, which may crack or damage tusks. Very long tusks are more prone to be broken than short ones, similarly to long nails that are easily broken. The deep break causes blood loss and infection. Female elephants work in tourism. Elephant camps mostly use females,*

> *especially for ones that let tourists take care of elephants, not for riding. It is safe for tourists.* [EO17, South]

Financial drivers. In addition to animal management, tusk cutting is expedited by the financial needs of elephant owners. Elephant owners in all three regions referred to the financial needs of both their family, and elephant upkeep, which was met by income from harvested tusks. A Surin elephant owner clearly reflected these factors in tusk harvesting:

> *I will again cut the tusks if the elephants have difficulties with it or I, myself, have a financial need. Most elephant owners today will not grow long tusks because it is worth money, needed for living.* [EO2, Surin]

Some elephant owners listed livelihood expenses, including living expenses, school-related cost of family members, debt payment, vehicle purchase, as well as costs related to organizing traditional events such as religious ordinations and weddings. The cost of elephant food was stressed by most of the Surin elephant owners. The Surin mahouts related the increasing cost of elephant food to the decreased available area of elephant foraging areas, as this response of an elderly elephant owner illustrates:

> *Rearing an elephant today is impossible without cost. There were forests along Mun river where mahouts took elephants for wild foraging during day. We called elephants to go home at dark. So [we had] no cost of elephant food. Today, we cannot let elephants roam for food as areas are owned and crops are now cultivated. [There is] no place for elephants to forage, so we have to buy food for our elephants which costs us a lot of money.* [EO20, Surin]

The concern about the cost of food for captive elephants was illustrated by Elephant owner 2, who owns a male elephant:

> *There are many elephants at home today. We have problems with limited areas for keeping elephants and insufficient elephant food. Elephants are not allowed in reserved forests because they raid plants, even in some harvested rice fields as the field ridges are possibly damaged by the animals. The food problem is very tense during the dry season, we either*

> *source or buy the food from other provinces or regions which also costs us fuel. Elephant food in the dry season is mainly sugar cane plants, and crops after harvesting fruits such as banana, pineapple plants – not many choices. We pay for harvested banana plants, the whole plant, cut and brought back here by a truck. The monthly subsidy [subsidization from government to support elephant keeping] is not enough during the dry season [Feb-May] to provide a good volume of food for elephants. Other periods of the year are fine. [During the dry season,] I ordered a truck of pineapple plants from Rayong in the East for at least 20,000 Baht [c. USD 645] to share with other mahouts. It's not affordable for me to pay all myself. We also grow Napier grass, but it can't do well without water.* [EO2, Surin]

The financial needs of elephant owners have become an important driver for ivory harvesting as was described by these two interviewees with different financial backgrounds:

> *Villagers here [Surin] raise elephants for many generations and we keep elephants for our living. We are not rich. Cutting of ivory today almost relates to financial reason. Normal elephant owners like me cut tusks to meet the cost of living. Rich elephant owners don't want to cut it, [they] want to grow it long, and get complete and long tusks once the animal dies and even refuse any buying offer.* [EO3, Surin]

> *I have about 20 elephants, eight of them are males. I pay mahouts for keeping all elephants. I only cut small pieces of the tusk tip, particularly, for five males having sharp-tip tusks which is dangerous for people. I think elephant owners don't cut elephant tusks unless they have some troubles. Money trouble seems to be more for living life of mahouts todays.* [EO11, Surin]

2) Ivory use: decision making is also influenced by financial need

After obtaining tusks from elephants, about two-thirds of the elephant owners sell the tusks, whilst the remaining elephant owners non-commercially use or gift (hereafter keep) the tusks. Non-commercial uses largely reflect the personal retention of tusks by the owner. A few interviewees mentioned giving tusks to relatives and friends without payment. Decisions about using the tusks is driven by the financial needs of elephant owners, market price, sentimental values, and ivory beliefs as outlined in Section 2 of *Figure 5*.2.

Financial drivers. Coincident with the harvesting step, financial factors play an important role in determining whether elephant owners keep or sell the tusks they harvest. About one third of elephant owners in my study choose to keep tusks. These elephant owners, in all three regions, referred to their stable financial background and other important sources of income such as businesses e.g., owning elephant camps, and farming products such as rubber or oil palm. In contrast, financial factors are highly relevant to elephant owners whose livelihoods depend on keeping elephants, as described earlier by the Surin elephant owners. Most elephant owner participants sold the ivory they remove or cut from their elephants. The selling decisions were related to their financial needs and were largely aimed at the harvesting step as explained by a Surin elephant owner:

> *I wanted a truck for transporting my elephants. My son told me to cut tusks for selling and I did. I used this money about 200,000 Baht [c. USD 6,450] for the down payment of this truck.* [EO6, Surin]

When a tusk is cut for selling, arrangements to sell the tusk are usually made in advance.

> *Most of the elephant owners here talk with local ivory shops about an incoming tusk cutting, if the shops want to buy tusks, and the prices they offer. I sold to the one with the highest price or sometimes I sold to the same buyer who bought my tusks before. When we, myself and tusk buyer, agree on the price, I cut the tusks. Buyers sometimes know about cutting from others, so they are the ones who contact me and give offers.* [EO9, Surin]

Market price. Elephant owners refer to the increasing price of tusks because of increased market demand. This increase in price influenced their decision to sell:

> *Elephant owners, in early days, kept cut ivory for their children, relatives and friends; did not aim profit from tusks. At that time, ivory price was low or even unable to sell. Later, there were buying offers for tusks with a high price so elephant owners can earn good money from selling tusks*. [EO11, Surin]

Some selling is also delayed until the ivory price is higher.

> *Southerner [Southern elephant owners] mostly kept ivory, they may sell them later when getting a high price, gaining good profit.* [EO22, South]

Most elephant owners also related the increase of Thai ivory price to the legal reform prohibiting entry of African ivory into Thai market such as:

> *Having law is good, it brings up price of legal tusks.* [EO3, Surin]

> *[There is] no foreign, cheap, tusks now, only Thai tusks, so we can sell our tusks at a very good price.* [EO18, South]

Elephant owners normally earn incomes ranging from 20,000 – 45,000 Baht (approximately USD 800 – 1,450) per kilogram for cut pieces (Bank of Thailand, 2019). The value of a pair of complete tusks is higher than for cut pieces; the value reflects not only weight, but also the shape and other physical characteristics of the ivory. The reputation of the elephant also influences tusk price. Cut pieces from a popular tusker were sold for up to three times higher than other elephants' tusks.

> *I could get millions of Baht from selling a whole pair of ivory from my elephant if the animal dies. That money might buy me two elephants. This elephant has very long tusks. He has been filmed many times, he is quite well-known. I once offered his cut pieces of tusks to a Royal family member. His tusks are wanted by anyone. Ivory traders [Manufacturers] here paid me 60,000 Baht [c. USD 1,935] a kilo, during 2015 - 2016, so they got these tusks for making items.* [EO4, Surin]

Sentimental values. Elephant owners who desired to keep tusks described the sentimental values of tusks including the pride of the owners of the elephants, remembrance of family members, family inheritance, and mahout-elephant bond. The transactions of tusks from elephant owners to users e.g., family members, relatives, friends, generally do not involve monetary exchange.

> *I mostly keep the tusks and give some to my relatives. My family has elephants, so we should have elephant tusks for remembrance. I do not have a money issue, and do not think of selling the tusks, want to keep them, it is valuable to my feeling. Friends also asked for ivory pieces for making ivory items for their uses, I also gave some to them.* [EO17, South]

> *I myself share ivory with my siblings and I want them to keep it. My father had 5 - 6 elephants and later was killed by an elephant. Our family had been insulted about keeping inherited elephants after father died. I have proved that I can take care of all father's elephants. Ivory of elephant has sentimental values for me to remember my father who took care of our family with income from elephant uses.* [EO22, South]

Beliefs. Beliefs in the protection and propitious properties of ivory were mentioned by most elephant owners. A naturally broken piece is sought after by believers, a reason for keeping tusk pieces:

> *Elephant owners normally sell cut pieces, but we want to keep broken pieces because it is naturally cracked, not an exploit. It does not happen frequently, so it is sacred. This protects us from bad things. Even today, people seek for these. If elephants do not want to give these pieces to anyone, no one finds those breaks, even if they seek hard.* [EO12, North]

One elephant owner revealed his desire to keep tusks, even though that was likely to be impossible given his current financial position:

> *I thought that would be good if I could keep the tusks. If there were no financial problem, I would keep tusks to inherit [to my] children. Rich elephant owners keep a lot of tusks from either their own elephants or buying from others who need money.* [EO6, Surin]

3) Sale destination: ivory cuttings to manufacturers

The final factor affecting ivory supply is the sale destination (Section 3, *Figure 5.2*). When asking further about tusk buyers, most elephant owners that were interviewed referred to ivory manufacturers (traders) as the most frequent destinations for cut-pieces. Some Surin elephant owners sell whole tusks to general users. Factors influencing sale destination include market access, legal awareness of elephant owners, and the form of the tusk.

Market access. When compared with elephant owners in the North and South regions, Surin elephant owners have the advantage of ready access to local ivory manufacturers. The reputation of the Surin elephant village in Thatum also offers the opportunity for connecting with external markets (either general users or ivory traders). Elephant owners also sell their tusks to external markets to gain a higher price.

> *I will get better price if a buyer is from Bangkok. We can do delivery for them. My son got about four million Baht from selling four pairs of tusks. They were all completed tusks. I like to keep tusks long and remove tusks once the elephant dies because I get more money, and these tusks also can be sold to general buyers.* [EO8, Surin]

Communication about ivory cutting is initially by word of mouth and then spread to external buyers via intermediaries. The prevalence of social media provides an additional tool for advertising harvested tusks to a wider market.

> *Cutting of tusks news is well spread among locals. Buyers are both ivory traders and rich locals. Outsiders [buyers from outside of the area] know from locals who is also a middleman. Some also posted in*

> *Facebook or Line that there is a legal ivory cutting. So interested people can contact them.* [EO9, Surin]

Ta-klang elephant village in Thatum of Surin is well known countrywide as the home of domesticated elephants. The village has been promoted for tourism by local authorities, and the national government. There are hundreds of elephants living within the village and these animals are a potential source of ivory for general users and attract ivory buyers. Thus, elephant owners can demand a premium price. This fact was reflected by Surin ivory manufacturers who seek a lower cost for ivory from other regions.

> *Elephant owners here (Surin) sell tusks with a high price. Surin is famous about elephants, and there are ivory manufacturers. I bought raw tusks from this village [Ta-klang] and areas nearby 4 - 5 times, then later I sourced from other areas through group of elephant mahouts. I mostly now buy raw tusks from the South.* [TM3, Surin]

In contrast with the Surin tusk market, tusks from the South and North have limited access to the general market. Elephants are dispersed across regions and these areas are less known for elephant husbandry compared with Surin. With established elephant-related networks, Southern and Northern elephant owners tend to sell the tusks to ivory manufacturers.

> *I sold tusks to a Surin trader who I knew for a long time. Surin people might know me because I bought a Surin elephant at a high price. We gather cut pieces until it is much enough to sell. The trader asked me to source tusks from around here for him too. My friend got 350,000Baht [c. USD 11,300] for about 10 kilogram of cut pieces.* [EO18, South]

> *There are many elephants in the North. Elephant owners know each other both within and outside the region. We know others since we looked for an elephant to buy. I sold my tusks to the same ivory trader in the North. When other elephant owners asked me where to sell the tusks, I also suggested the ones I knew. I now source tusks to supply an ivory manufacturer in the North.* [EO6, North]

> *I bought tusk from everywhere both local and other provinces and regions. I rarely buy tusks from the South. Tusks in my shop are mostly from the North, for example Nan, Phrae, which is closer. People know I have an ivory shop, and buy their elephant tusks. They further tell elephant owners or people want to sell tusk to sell tusks to me. It's hard to find general buyers; they don't know who wants tusks. Also buyers, themselves, have no idea where to get tusks, except from ivory shops and Surin*. [TM16, Petchabun]

Legal awareness. I asked participants about the legal requirements related to tusk-supply activities, including sales. Their responses demonstrated variable legal understanding. Variablity in legal understanding influences decisions on sale destination; elephant owners with limited legal awareness chose to sell tusks to authorised ivory manufacturers, rather than general users, to avoid legal difficulties. Manufacturers are better educated about legal requirements than are elephant owners (see Chapter 3). The legal awareness of elephant owners varies both between and within regions. Surin elephant owners are mostly aware of the legal provisions related to the cutting of tusks, whilst North and South elephant owners generally are confused about the complicated requirements of ivory registration. The manufacturers facilitate the operations of elephant owners who lack legal understanding of the arrangements required to complete legal requirements e.g., by offering transport to ivory registration offices, and assistance with consultations with ivory registration officers.

> *I do not know details about the ivory-related law. I sold tusks only to local ivory shops here (Surin) where they arranged all [the paperwork] for me.* [EO2, Surin]

> *Transfer of tusks will be done at a forestry [DNP] office. If selling to Surin [ivory] traders, they know very well about legal procedures. They liaise with authorities which is easy for me. Before having the law, we did not have to inform the government, only used an elephant identification document.* [EO18, South]

> *Some elephant owners in the South do not know the law because they do logging in remote areas. I spend a week both for traveling and arranging tusks buying there. Even if it is very far from here, the tusks are much cheaper. They [the prices] are also negotiable.* [TM3, Surin]

A lack of legal awareness amongst general users likely narrows the available market for elephant owners as explained by a Surin ivory manufacturer:

> *Today, there are not many raw ivory buyers [general buyers] that directly get tusks from elephant owners. General buyers are afraid of buying it because they are unsure about laws. Elephant owners then have to sell the tusks to us [manufacturers].* [TM4, Surin]

Tusk forms. Tusk form (cut pieces or whole tusks) also determines buyer group. General users normally seek a pair of complete tusks with sharp tips for decorative purposes. Cut pieces are largely destined for ivory manufacturers. As this elephant owner explained:

> *Cut piece are mostly sold to ivory shops [manufacturers], not sold for use as decorative tusks because there is no tusk cavity, [they are] not complete and big. Tusks that people use for decoration are those that were removed from a dead elephant.* [EO2, Surin]

Manufacturers also bought whole tusks. Suitable ivory items can be manufactured in response to tusk size and sharp. A larger size is preferable. For example, a 3.5 inch (*c.* 9 cm.) diameter piece can produce bangles that would pay back the material cost.

5.3.3 Annual ivory supply from Thai domesticated elephants

The estimate was based on raw ivory obtained from elephant management cuttings, breaks, and removals from dead elephants during 2015 - 2019 (*Table 5.2*). Annual ivory production from domesticated elephant in Thailand is, at least, *c*.380 kilograms on average. Around 36% of the weight was under commercial-held possession.

Table 5.2: Minimum stock of raw ivory obtained Thai domesticated elephants during 2015 - 2019. *Data from trader acquisition records under Elephant Ivory Act, and issuances of Transportation permits by Department of Livestock Development, and certificate of ivory origin by Department of Provincial Administration. The estimate of private-held ivory is a minimum.*

Year	Raw ivory stock (kg)		
	Private	**Commercial**	**Total**
2015	301.8	122.6	424.4
2016	327.8	190.7	518.6
2017	181.2	72.4	253.6
2018	212.7	178.8	391.4
2019	176.5	119.5	296.0
Total	1200.0	684.1	1884.0
Average	240.0	136.8	376.8
Percentage	63.7%	36.3%	100%

The flow of commercial stock is shown in *Figure 5.3***.** Key sources of the commercial stock were Northeast (37%), South (31.5%), and North (31%). Around 70% of the stock was transferred to Surin ivory manufacturers, who sourced raw material from the countrywide, whilst half of the proportion was from local elephants followed by raw ivory from South region. Whereas the key sources for Northern ivory manufactures (Nakhon Sawan and Uthai Thaini) were mainly the provinces in the North, together with external source from the South region. There were transfers of raw ivory between ivory manufactures.

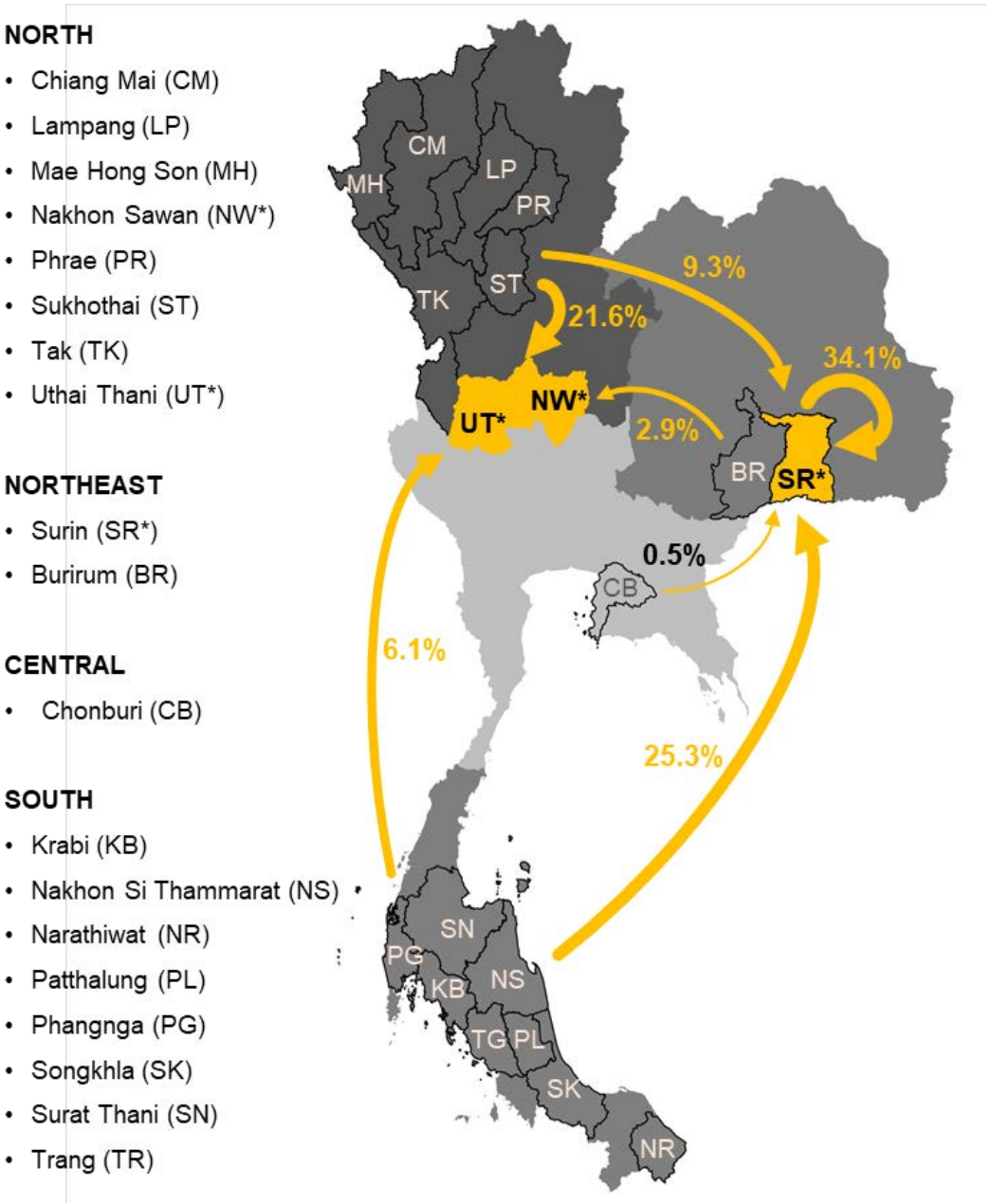


Figure 5.3: Flow of raw ivory to ivory traders.*Proportions were calculated based on the total newly-obtained stock (684.1 kg). Yellow areas marked with * indicated manufacturing sites. The width of the arrows represents the proportional weight of raw ivory.*

In addition to the newly-obtained ivory, ivory traders obtained ivory supply from privately-held stock. During 2016 - 2019, the annual volume of raw ivory that transferred from pre-law registration stock (private-held registration) approximately was 30 kg accounting for 17% of annual ivory supplied for ivory trade (170 kg a year).

5.4 Discussion

5.4.1 Thai ivory supply chain

Supply studies can be beneficial for the management of the wildlife trade. Studies of the bushmeat supply chain, for example, have recommended comprehensive monitoring and management of the trade at all steps along the chain (Boakye et al., 2016; Cowlishaw et al., 2005). Additionally, studies have found that the bushmeat market is driven by supply, thus policy effort to reduce hunting would likely decrease the market overall (McNamara et al., 2016). An analysis of the illegal ivory chain provided a comprehensive understanding of the trade to assist countries in designing appropriate policy responses (UNODC, 2020b). In that analysis, the structure and mechanism of the chain guided enforcement actions to be more specific to relevant actors in source countries, while consumption nations should tailor suitable prevention measures around ivory smuggling.

The legal ivory market is controversial due to its potential to mask the laundering of the illegal supply (Bennett, 2015). For this reason, comprehensive controls of the market are needed to ensure that only legal products enter the supply chain. The supply chain of ivory includes different groups of actors who facilitate the flow of traded items to end users (UNODC, 2020b). Understanding the role and function of these supply chain actors will assist in monitoring the trade.

I identified key actors in the Thai domestic ivory supply chain, and their interactions along the chain. A comprehensive monitoring plan would target these actors. In theory, with stable demand the availability of illegal stock should decrease the price of Thai ivory. Regular observation of the raw ivory volume flowing into manufacture, and the market price, would flag possible market change, as well as indicate the possibility of illegal stock within the market. The input volume of tusks from existing registered stock or ivory consumers to the manufacturing process should not be missed as this will be a surplus to the chain in addition to newly harvested tusks.

5.4.2 Legal ivory from elephant domestication

Ivory from domesticated elephants is a renewable resource. A substantial number of the raw tusks supplied to the ivory market come from the management of domesticated elephants. Dead animals provide one set of whole tusks (Phuangkum et al., 2005), while live domesticated elephants can provide tusk pieces on multiple occasions during an animal's life. Tusk length depends on tusk use and the wear rate, as well as tusk growth rate (Sukumar, 2003). Wild elephants use tusks to collect food etc., a practice which results in natural shortening of the tusk via wear and cracks (Vanapithak, 1995). Oversize tusks can impact the elephant's quality of life (Sukumar, 2003), therefore cutting the tusks of domesticated elephants is necessary for elephant healthcare, human safety and work competence. Tusk cutting is common practice in elephant domestication and conducted in non-lethal manner in contrast to tusk from wild elephants, especially African elephants.

At the first national registration of the domesticated elephant ivory in Thailand in 2015, c. 160 tons of pre-law raw ivory were privately-held stock and about 500 kg. involved commercial possession (Krishnasamy et al., 2016). Each year, Thai domesticated elephant supplied, at least, ~375 kilograms of raw ivory. This volume coincided with the annual estimation of ivory supply, 300 - 400 kg, produced by Thai domesticated elephants (Stiles, 2009). Recognizing limitation in compiling data under private possession in my study, I emphasized my estimation as minimum volume. Present government records allow long term monitoring of the supply to improve this knowledge.

About 36% of the annual supply volume, together with ivory transferred from private-held possession, accounts for around 170 kilograms of the ivory supplied commercial domestic trade of ivory in Thailand. On the basis of the volume for the commercial ivory stock flow, Surin is currently the most important manufacturing site. This situation might be related to high number of ivory shops within the province (c. 40 shops), elephant tradition reputation of the area, as well as capability in production of plain product types e.g., beads and parts of necklace, in high quantity. Fine carvings are known to be produced from the Nakhon Sawan manufacturing site (North), a practice reflecting the origin of ivory carving in Thailand (Stiles, 2003, 2009) and the presence of master carvers n (S. Arbhassarosakul, pers. comm., 2018). Elaborated carvings would take longer period in production with

limited number of carvers todays; for example, a master carver in Chainat, bordered to Nakhon Sawan and Uthai Thani provinces, spent at least a month for a 1 inch (2.5 cm) elaborate Singha (lion) figurine (S. Arbhassarosakul, pers. comm., 2020).

Decision making in relation to the supply, harvesting and selling of elephant tusks, is largely driven by the financial needs of elephant owners, in particular mahout elephant owners, who comprise the majority of elephant owners. A study of domesticated elephants in the Northern tourism industry reported that almost 40% were owned by mahouts (elephant keeper), followed by camp owners, and non-mahout owners, respectively (Godfrey & Kongmuang, 2009). In my study, most of the elephant owners were mahouts in an uncertain financial situation, who used the extra income from selling elephant tusks to meet their household and elephant keeping costs. Evidence presented in Chapter 3 demonstrated that many elephant owners have limited knowledge around relevant laws. In this chapter, I found that this limitation posed a burden to them to access wider market and likely result of lower price of raw ivory. Thailand's tourism industry, from which most elephant owners gain their incomes has been heavily impacted by the COVID pandemic ("COVID 19 pandemic causes many elephants unemployed," 2021; Thai Elephant Alliance Association, 2021). As such, the financial problems of many elephant owners are likely to have increased. Sale of ivory would support the cost of living of these elephant owners.

The decision to sell tusks is also affected by their market price. Keeping raw tusks for later sale, at a higher price, is an option for some elephant owners as ivory can be treated as an investment due to its durability and minimal storage costs (Moyle, 2014). Legality is also a significant determinant of ivory market price (Sosnowski et al., 2019); the high value of ivory is a consequence of the 2015 legislative reform. Effective legal restriction prevents the entry of illegally sourced ivory, increasing the value of legal sources of ivory (Stiles, 2009). Prices of legal, raw ivory considerably increase about USD 1,000 per kg greater than 2001's raw ivory price (USD 100–250/kg) (S. Arbhassarosakul, pers. comm., 2020; Stiles, 2009). A similar change in the price of raw ivory was also reported in Japan after the international ivory ban (Menon & Kumar, 1998).

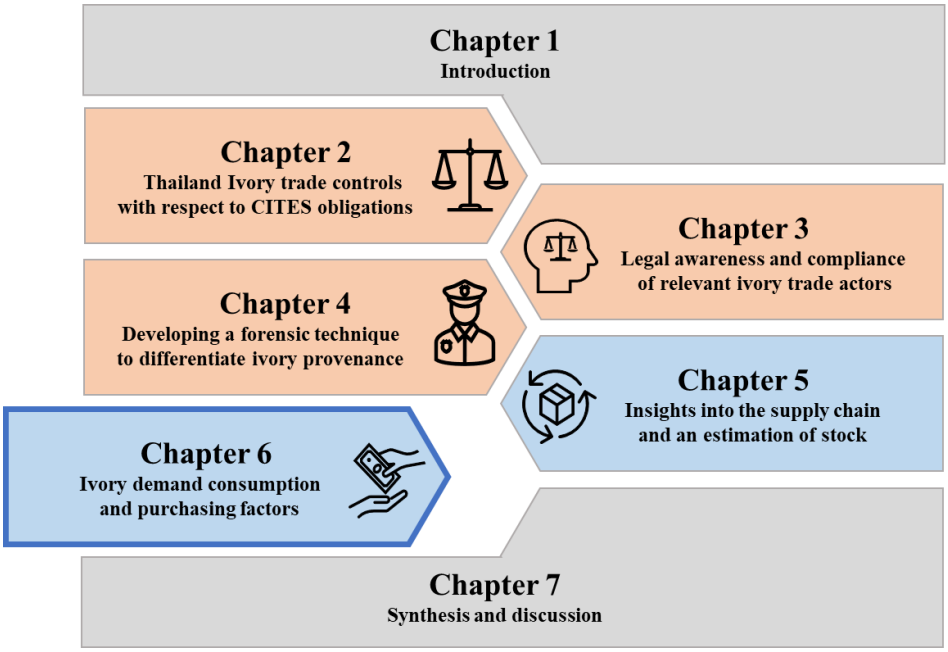
As the illegal trade impacts on the survival of elephants and violates CITES, that Convention recommends that the domestic market, which may contribute to elephant poaching or the illegal ivory trade, be closed as a matter of urgency (CITES Res.Conf. 10.10 (Rev. CoP18), 2019). This action would pose potential risks to the livelihoods of Thai elephant owners, as well as actors along its supply chain. My research also revealed the positive attitudes of elephant owners to legislation deterring the entry of illegal ivory, as consequence of the 2015 legal reforms (Chapter 2), that has resulted in the high price of legal ivory in Thailand. This economic incentive should result in elephant owners, who directly benefit from the robust legal measures and existence of the domestic legal market, complying with the relevant Thai laws.

5.5 Chapter summary

- The legal Thai ivory market is dependent on supply from local domesticated elephants. Knowledge of the supply chain is important for managing this market in order to achieve sustainable benefits for both wildlife conservation and human livelihoods.
- In this chapter, I mapped a legal domestic ivory supply chain, and identified five key actor groups: elephant owners, intermediaries, manufacturers, retailers, and ivory consumers. Pre-existing networks of elephant owners facilitate the flow of raw ivory. Intermediaries are involved in the raw ivory trade, particularly among regions. The legal knowledge of intermediaries, taking roles as information breakers, should promote legal transactions of ivory. Recognizing the greater knowledge of the elephant owners who are intermediaries (Chapter 3), awareness raising should benefit from this situation in similar way to the potential of ivory traders educating other connecting actors.
- The legal ivory trade is clearly beneficial to Thai elephant owners, particularly for mahout owners, who earn their living from keeping elephants. However, mahout owners vary in terms of market access. The sale of tusks is increasing through time, likely due to increased financial pressures on elephant owners and market factors that increase the price of raw ivory. This chapter documented the importance of legal awareness among elephant owners (Chapter 3) in accessing to public user buyers.
- The annual supply of raw ivory from domesticated elephants is, at least ~375 kg, with around one third if this supplied to ivory product manufacturing. Surin is currently the most important manufacturing site based on flow volume for the commercial ivory stock.
- Monitoring the supply chain would provide valuable information on changes in supply e.g., volume and price, trade pattern, for market management. The insights from such monitoring would enable the identification of further needs for investigation and enforcement, particularly using the NIRS technique described in Chapter 4.

Chapter 6: Ivory demand consumption and purchasing factors

I explore ivory consumption in regard to knowledge around market dimensions. Understanding factors influence people's decision in purchasing ivory is important for informing targeted behavioural intervention, e.g., communication strategies, social campaigns. I use self-administrated surveys to explore the attitudes of ivory shop customers, a group of ivory consumers. This approach aims to collect information on factors associated with ivory purchasing, including how ivory shop consumer behaviour in response to the introduced legal provisions.



Publication

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6.1 Introduction

An unsustainable wildlife trade, and trade in wildlife products, threatens both the species being traded and the long term future of rural economies (Peres, 2010). Measures to address sustainability concerns include applying enforcement approaches to diminish illegal supply (Broad et al., 2003; Challender & MacMillan, 2014; Phelps et al., 2014). Enforcement approaches include investments in policy and resources to prevent poaching in the species of concern's countries of origin, along with strengthening detection measure to curb smuggling across borders (Challender & MacMillan, 2014). Interventions have been extended to include the ultimate driver of the wildlife trade: demand. Public education and social marketing have sought to alter behaviour in wildlife consumption (Veríssimo et al., 2020). To maximise the effectiveness of such interventions, insights into factors such as customer preferences, purchasing behaviours and the social dynamics of purchasing is necessary (Challender & MacMillan, 2014; Veríssimo et al., 2020). These insights would also be helpful for tailoring interventions on the supply side of the trade (Thomas-Walters et al., 2021).

Factors related to the individual (e.g., personality), social (e.g., education, age, income, religion) and information (e.g., knowledge, media) provide the background to consumers' beliefs about appropriate behaviours and attitudes, norms and perceived constraints to behaving in certain ways (Ajzen, 1991). Consumption behaviours, therefore, are influenced by various factors including social, culture, personal, and psychological contexts (Veríssimo et al., 2020). For example, an individual's perception about how people who are important to them might perceive a particular consumptive behaviour may influence how likely that individual is to consume in that particular manner. Similarly, an individual's belief about the likely outcome of a particular behaviour, such as that purchasing a particular item will lead to good fortune, also influences their consumptive patterns. Understanding the relative strength of specific drivers of consumption, therefore, allows for the design of more targeted interventions.

Research into the diverse drivers of consumption of wildlife and wildlife products can provide recommendations to suit relevant interventions (Thomas-Walters et al., 2021). For example, a study of ivory consumption in China documented a demand for ivory artwork as an investment; effective management of ivory consumption should thus involve the participation of relevant sectors such as the art investment community and cultural preservation groups (Gao & Clark, 2014). In accordance with a finding that the majority of Cambodians involved in bear bile consumption trusted biomedical practitioners, interventions to reduce demand would be most effective if they focussed on biomedical uses (Davis et al., 2020). Thomas-Walters et al. (2021) suggested evidence-based strategies, such as: (1) promoting artificial propagation of deliberately coloured cultivated orchids to displace wild-collected orchids that are targeted for colour, and (2) reducing demand by targeting traditional medicine practitioners, who prescribe seahorse medications, rather than their customers, who are likely to be seeking any medicine with a reputation for curing arthritis.

Thailand permits a commercial ivory trade for domestic consumption, based on raw material legally sourced from local domesticated elephants. USAID Wildlife Asia (2018) studied ivory and tiger consumption in different regions in Thailand and estimated that ~2% of Thais owned or used ivory products. Their ivory purchases were largely motivated by supernatural beliefs e.g., ivory brings good luck, is spiritual, and protects from harm, whilst ivory aesthetics, value and social image were lesser motivations for purchases. The purchased items mostly involved small products, e.g., jewellery and spiritual items. However, the study did not specifically explore the purchasing factors and attitudes of ivory buyers in relation to ivory shops.

As explained in Chapter 2, the Enactment of Elephant Ivory Act 2015 regulates commercial trade via authorized ivory shops (Chaitae, Gordon, et al., 2022; Elephant Ivory Act B.E. 2558, 2015). To address Objective 2 of this thesis, I conducted research aimed at understanding the attitudes in of people who purchased ivory at specialist shops throughout Thailand. I sought to explore how characteristics of ivory shops influence the decision making of their customers in order to provide an evidence base for management of the Thai domestic ivory trade.

6.2 Methods

6.2.1 Data collection

I administered a structured survey between April 2020 - June 2021, using purposive sampling. This technique is a non-probability sampling *method* to identify prospective participants who possess characteristics or qualities of research interest (Etikan et al., 2016). Copies of the self-administered survey were placed in ivory shops and DNP offices countrywide to maximise its accessibility to (potential) ivory customers who are target participants. Despite the COVID pandemic, ivory shop customers were recruited either directly from on-site registered ivory shops or indirectly at the offices of the Department of National Parks, Wildlife and Plant Conservation (DNP) for those registering purchased ivory items. The survey asked questions about ivory consumption and participant demographics (*Info S6.1*). Survey questions included how the buyers learned about the shop, the nature of ivory items they wished to purchase, factors influencing ivory purchases, and beliefs and values related to ivory. All participants were provided with information regarding the survey, which was in Thai. This information contained how participation was voluntary and anonymous, as well as implied consent as completion of the survey as approved by the James Cook University Human Ethics Committee (H7873). In total ninety-two copies of the survey were returned: 83 surveys completed at ivory shops in Nakhon Sawan, Uthai Thani, Petchabun, Sukhothai and Surin, and 19 copies collected from DNP Ubol Rachatani and Bangkok offices.

To explore potential differences between ivory consumer groups, I compared demographic data from the consumption survey respondents with those of Bangkok ivory possessors obtainable from the legal awareness study by the authors (Chapter 3). The demographic profiles of the Bangkok ivory possessors were obtained from 497 surveys completed by anonymous Bangkok respondents who registered ivory under possession with the DNP under the Elephant Ivory Act 2015. The legal awareness survey was conducted during May 2020 - May 2021 and is reported in Chapter 3. The chance of participants overlapping between two studies is small as only nine responses to the ivory consumption survey were obtained from Bangkok.

6.2.3 Analysis

Statistical analyses were performed using IBM SPSS Statistics 27 (IBM Corp, 2020). Non-parametric tests were applied as the data were not distributed normally. Demographic data of the ivory shop customers and the ivory possessors from Bangkok (Chapter 3) were compared using a Chi-square test. Mann Whitney U and Kruskal-Wallis tests were used for comparing the difference between categories such as gender. Associations between variables were explored using the Spearman correlation test. Religious information was excluded from relationship analysis due to a significant bias in number. Religious information was excluded from the relationship analysis because Buddhist respondents comprised 97% of the sample and the consequential very small sample sizes of the remaining religions. Small and uneven sample sizes prevented categorization by geographical area.

6.3 Results

6.3.1 Characteristics of ivory consumers

Table 6.1 presented demographic profiles of ivory consumers obtained from ivory shop visitors and Bangkok ivory possessors, ivory shop visitors consisted of similar proportions of males and females. The largest proportion of visitors was 41 - 50 years old (30.8%), followed by the 51 - 60 years old group (26.4%). Most visitors held a university degree (61%). The visitors were largely employed in either government or private sectors (70% combined). Almost 32% of the visitors had monthly incomes of between 15,001 and 30 000 Thai Baht (USD 435 - 870), whilst the lowest proportion of the visitors (10%), earned ≥ 60,001 Baht (USD1,740) per month.

I compared the demographic profiles of the two groups of Thai ivory consumers using Chi-square tests. There were significantly differences between the respondents and the Bangkok ivory possessors, with respect to age class, education level and occupation (*Table 6.1*). More than 55% of the Bangkok ivory possessors were ≥ 61 years old, in contrast to the consumption study where this age class represented the lowest proportion; about half the respondents were aged 41 - 60 years. Education level also differed between respondents in the two studies. People with university education level were the largest

group in both studies, but varied in proportion among education levels. A university degree was held by around 80% of Bangkok ivory possessors, while a smaller proportion of countrywide ivory customers (66%) had the same education level. Around 50% of Bangkok ivory possessors were non-working people; only 4.4% of the shop visitors did not work.

Table 6.1: Demographic profiles of two groups of Thai ivory consumers*:1) the ivory shop customers and 2) the Bangkok ivory possessors. Comparisons were conducted using Chi-square tests on data for both groups. Bold indicated significant difference at the 0.05 level. Sample sizes were 92 for ivory shop customers, and 497 for the Bangkok ivory possessors.*

Demographic	**Category**					**Chi-square test**	
						value	***p***
Gender	**Male**	**Female**					
Ivory shop customers	50 (54.3%)	42 (45.7%)				0.327	0.568
Bangkok ivory possessors	254 (51.1%)	243 (48.9%)					
Age class (years)	**19 - 30**	**31 - 40**	**41 - 50**	**51 - 60**	**≥61**		
Ivory shop customers	16 (17.6%)	14 (15.4%)	28 (30.8%)	24 (26.4%)	9 (9.9%)	**117.361**	**<0.001**
Bangkok ivory possessors	6 (1.2%)	30 (6.0%)	63 (12.7%)	118 (23.7%)	280 (56.3%)		
Religion	**Buddhist**	**Others**					
Ivory shop customers	90 (98.9%)	1 (1.1%)				0.913	0.339
Bangkok ivory possessors	483 (97.2%)	14 (2.8%)					
Education level	**Primary school**	**High school**	**Diploma**	**University**			
Ivory shop customers	4 (4.3%)	16 (17.4%)	11 (12.0%)	61 (66.3%)		**10.822**	**0.013**
Bangkok ivory possessors	17 (3.4%)	53 (10.7%)	26 (5.2%)	401 (80.7%)			
Occupation	**Business owned**	**Private employee**	**Government employed**	**Do not work**	**Others**		
Ivory shop customers	22 (24.2%)	29 (31.8%)	34 (37.4%)	4 (4.4%)	2 (2.2%)	**112.63**	**<0.001**
Bangkok ivory possessors	142 (28.6%)	76 (15.3%)	34 (6.8%)	245 (49.3%)	0		
Monthly income (Baht)	**≤15,000**	**15,001-30,000**	**30,001-45,000**	**45,000-60,000**	**≥60,001**		
Ivory shop customers	18 (19.8%)	29 (31.9%)	20 (22.0%)	15 (16.5%)	9 (9.9%)		

6.3.2 Ivory consumption behaviours

6.3.2.1 Shop locator

All age classes of visitors to the ivory shops were largely influenced by recommendations from others (41.9%), followed by the shop already being known to the visitor (20.4%), internet search (14%), and other options (*Figure 6.1*). Such recommendations were particularly important for visitors aged 51 - 60, 19 - 30, and 41 - 50 years. Knowing the shop was the major reason for visiting for a quarter of the visitors in all age class, except the 19 - 30 year old class. The 19 - 30 year old age class were also influenced by shop location (20%). Internet searching involved people in all age classes, especially customers aged 31 - 40 year old (33%). Almost 20% of 41 - 50 year old visitors found about the shop through a promotion event. A small proportion of respondents was passing by (4 - 11%), especially those 61 years old and above (11%).

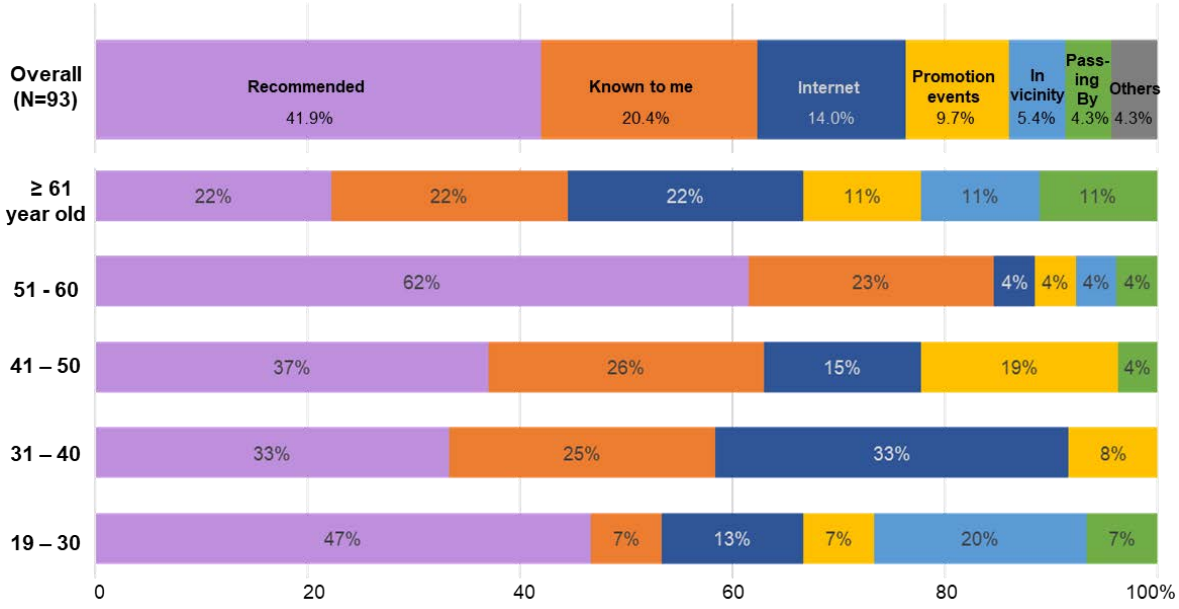


Figure 6.1: Mechanisms by which ivory shop customers selected the shop to visit by different age class. *"Others" option was excluded from the analysis for age class categories.*

6.3.2.2 Ivory items

A wide range of jewellery and parts thereof (77%) were of interest to the ivory shop visitors (*Figure 6.2*). The most three popular items were necklaces (23%), bangles (16%) and rings (12%). Belt buckles (13%) and sacred items (8%) were also sought; only 2% of the visitors aimed to buy raw ivory. Female visitors were most interested in types of jewellery, except for necklaces and beads/parts, which were largely sourced by males. Males were also the main buyers of non-jewellery products i.e., belt buckle, sacred products. Raw ivory was purchase of choice only by male visitors.

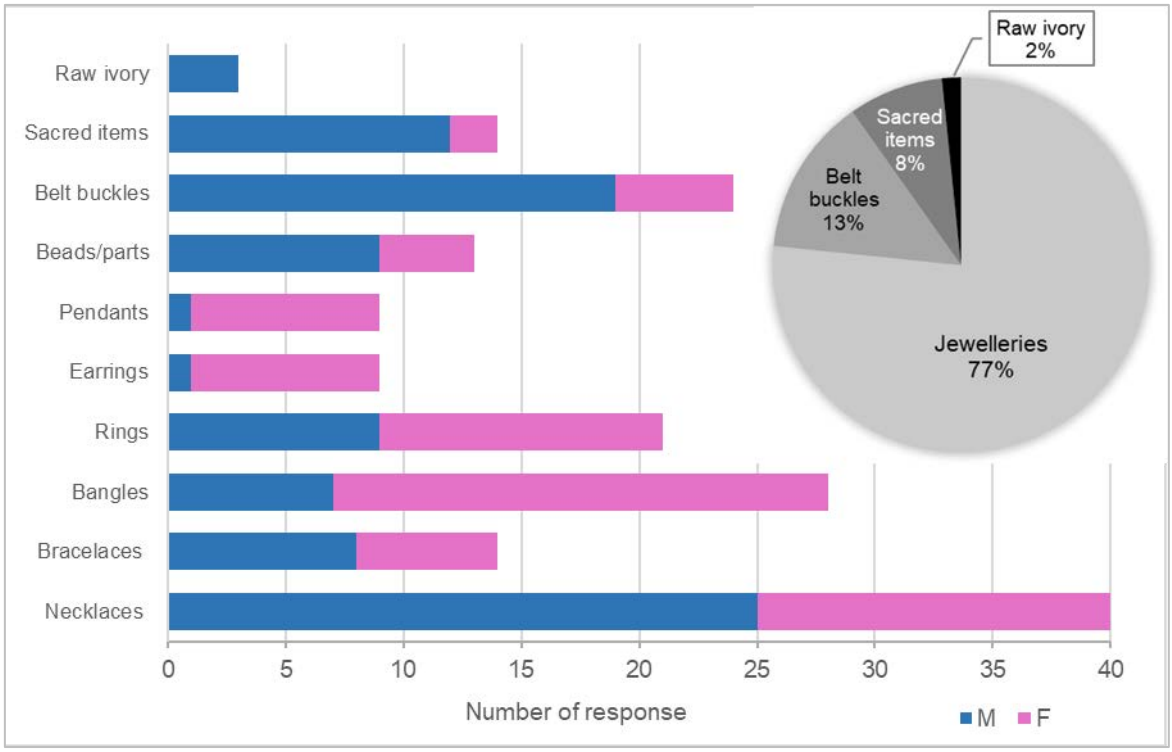
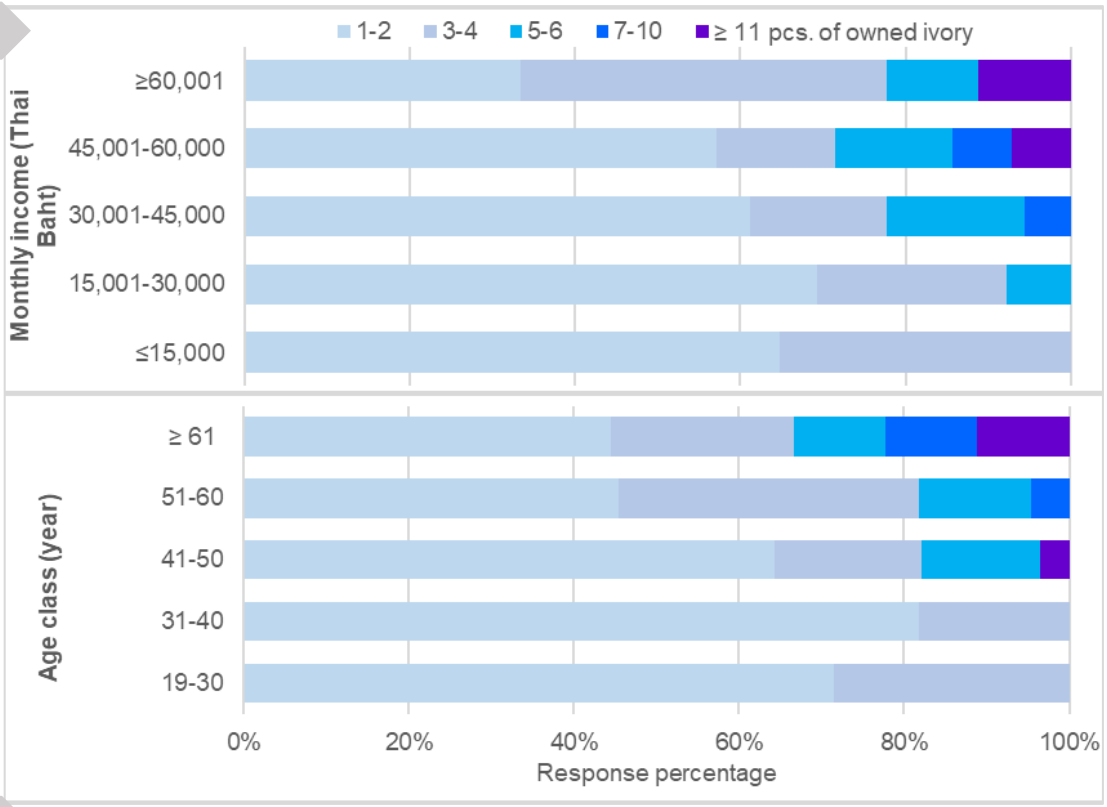


Figure 6.2: Ivory items of interest to the ivory shop visitors.

A Spearman correlation test showed a positive relationship between the number of ivory items owned and the age class of respondents (p=<0.009). Younger ivory consumers (< 40 years old) owned 1 - 4 pieces; older people owned more with the highest proportion having > 5 pieces (*Figure 6.3*). There was also a positive relationship between the number of ivory pieces owned and income as well as age (p=<0.001).

a



b

Respondent characteristic	Correlation Coefficient	*p*	N
Possessed ivory and Monthly income	0.215*	0.050	84
Possessed ivory and Age class	0.282**	0.009	84
Age class and Monthly income	0.473**	< 0.001	90

Figure 6.3: Number of pieces of items owned by survey respondents classified by age class and monthly income (a), and their correlations (b)*;** and * indicated correlations significant at the 0.01 and 0.05 levels, respectively.*

6.3.2.3 Other characteristic of ivory shop customers

Other consumption behaviours of the ivory shop customers are summarised in *Figure 6.4*. Above one-third of the shop visitors lived within 50 km (37%). Most visitors (60%) aimed to buy an ivory item (usually for themselves) while 34% came to have a look; 5.5% came for maintenance service. Most shop visitors bought their first ivory item themselves (80%); 19% were given their first piece of the ivory, for 1% the ivory was inherited (Table 2). One-third of the visitors did not know any ivory consumers, while the remainder indicated that they knew ivory consumers, either friends or colleagues (48.7%), relatives (31.6%), or others (19.7%). Most visitors (56%) had 1 - 2 pieces of ivory, followed by 3 - 4 pieces, only 2% had 7 - 10 pieces, a further 2% ≥ 11 pieces.

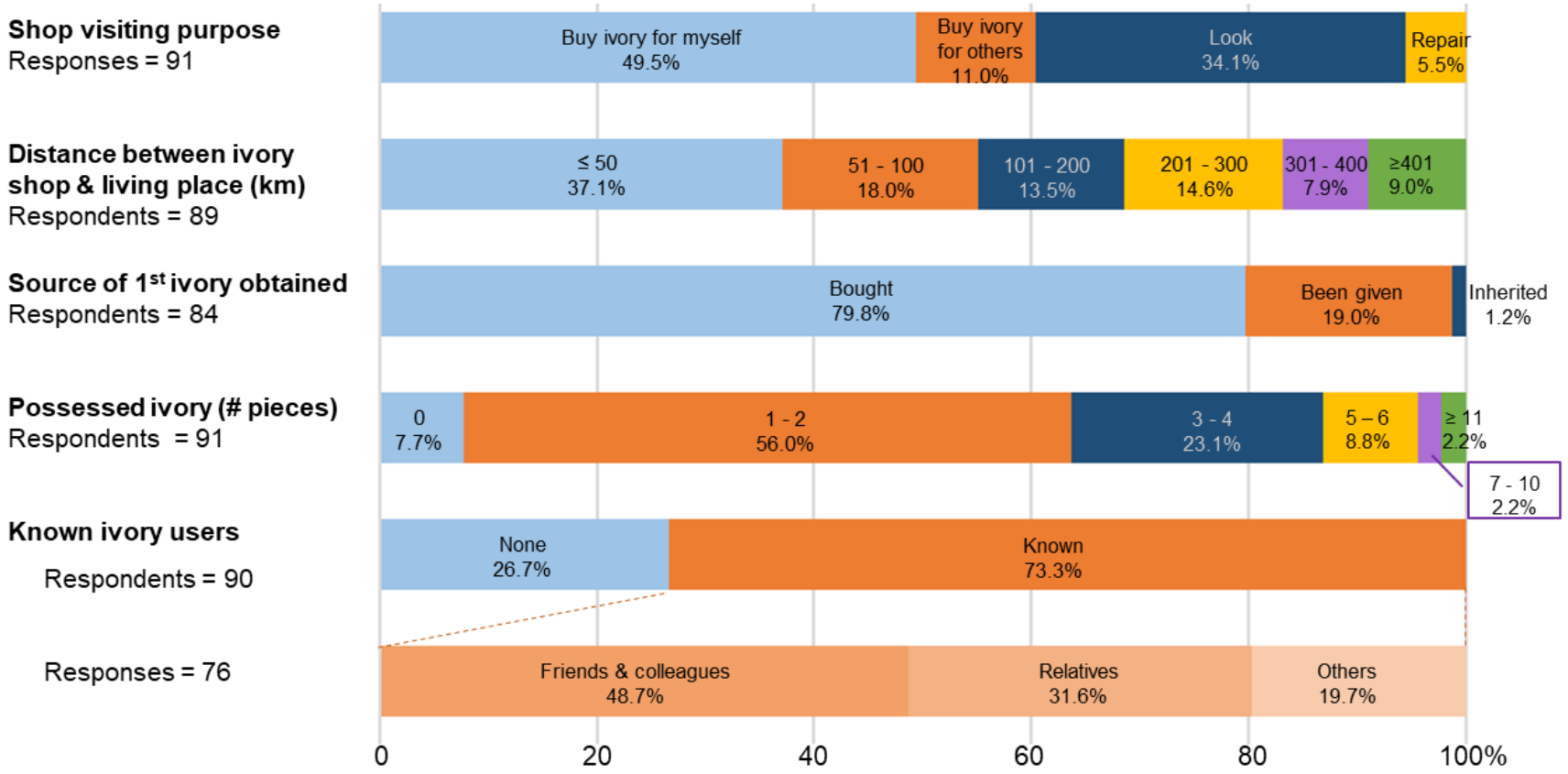


Figure 6.4: General characteristics of ivory shop customers.

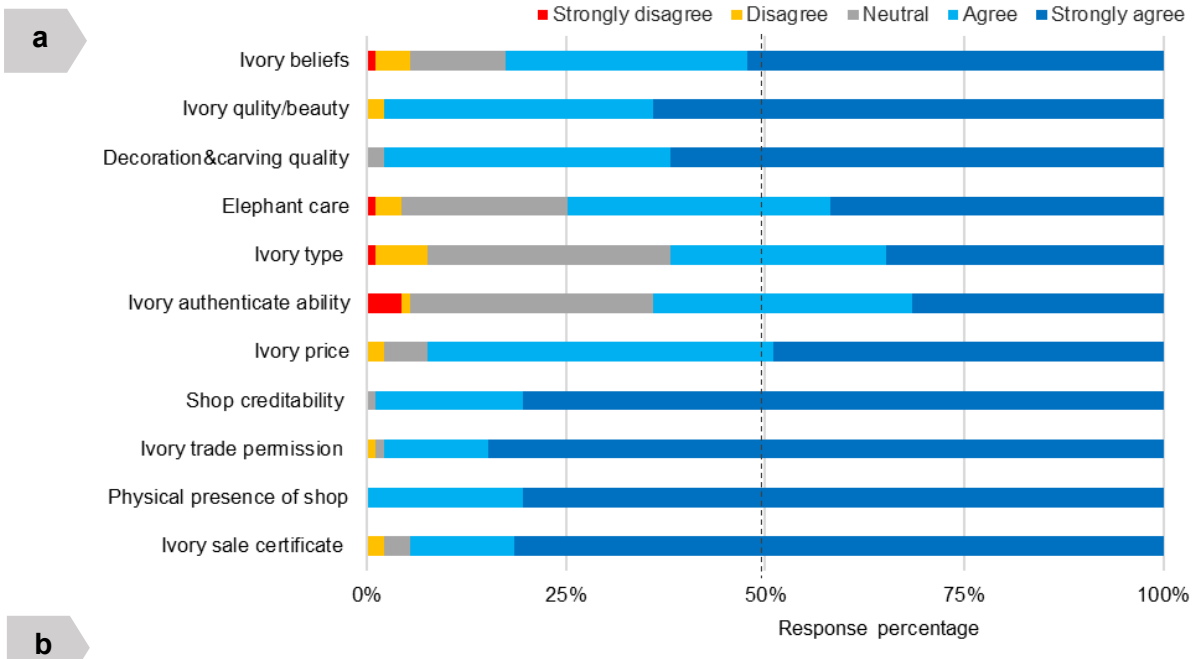
Repair refers to customers visiting shops to receive services for repairing damages or maintaining usable condition of ivory items or products e.g. restringing ivory beads of necklaces, cleaning. Percentage calculations were based on number of respondents for single-response question, or total responses for multiple-response questions as specified.

6.3.3 Purchasing factors

Ivory purchase was largely influence by factors relating to the ivory shop. i.e., shop creditability, trade permission, physical presence of shop, and use of ivory sale certificates (*Figure 6.5-a*). Less important were the aesthetics of the ivory purchase and its decorative features (carving/combined material) with medians of 2 "Strongly agree". Ivory price, elephant care, ivory types and ivory authentication ability all had lower median score at 1 "Agree". Ivory price yielded a higher frequency of positive responses (92.4%) compared with the other three factors. Most buyers agreed that ivory price influenced their purchase more than elephant care, ivory type or ivory authentication.

The highest correlations (*Figure 6.5-b*) between the factors influencing ivory purchase were among the four shop characteristics (r^2 0.783 – 0.828 (p=<0.001)). All factors were significantly correlated (p=0.01) either among or with most characteristics of the shop (i.e., creditability, trade permission, physical presence, and issuance of ivory sale certificate), . Ivory authentication was significantly correlated only with ivory type (p=0.01) and elephant care (p=0.05). Correlations were significant (p=0.01) among ivory-related factors 'i.e., ivory quality/beauty belief/value and decorations. All these results need to be interpreted with caution, given that some could be expected by chance alone.

Some additional influences on the choice of respondents included rarity of ivory, relationship/connection with elephants, as well as the worship of sacred items linked to faith in revered monks. Some respondents had a negative response to questions about belief, indicated by answers such as "*No belief at all*" [SC44]., "*Buying because of ivory beauty and its fine carving*" [SC66].



b

Factor	Ivory beliefs	Ivory quality/ beauty	Decoration & carving	Ivory authentication ability	Elephant care	Ivory type	Ivory price	Shop creditability	Physical presence of shop	Ivory sale certificate
Ivory quality/ beauty	0.369** < 0.001									
Decoration & carving	0.333** 0.001	0.663** < 0.001								
Ivory authentication ability	0.046 0.666	0.120 0.255	0.094 0.371							
Elephant care	0.177 0.094	0.253* 0.015	0.315** 0.002	0.253* 0.015						
Ivory type	0.055 0.604	0.134 0.204	0.221* 0.035	0.295** 0.004	0.450** < 0.001					
Ivory price	0.115 0.274	0.218* 0.037	0.292** 0.005	0.042 0.692	0.265* 0.011	0.421** < 0.001				
Shop creditability	0.379** < 0.001	0.303** 0.003	0.353** 0.001	0.022 0.839	0.353** 0.001	0.232* 0.026	0.415** < 0.001			
Physical presence of shop	0.315** 0.002	0.300** 0.004	0.405** < 0.001	-0.073 0.491	0.334** 0.001	0.226* 0.030	0.434** < 0.001	0.658** < 0.001		
Ivory sale certificate	0.298** 0.004	0.341** 0.001	0.466** < 0.001	0.029 0.785	0.361** < 0.001	0.350** 0.001	0.373** < 0.001	0.634** < 0.001	0.762** < 0.001	
Ivory trade permission	0.296** 0.004	0.304** 0.003	0.363** < 0.001	-0.030 0.780	0.349** 0.001	0.269** 0.009	0.438** < 0.001	0.788** < 0.001	0.783** < 0.001	**0.828** < 0.001**

Figure 6.5: Percentage frequencies of responses to ivory purchasing factors surveyed (a) and a matrix of the correlations between the various factors (b).

*The dashed line in a) indicates the median for each factor. Correlation matrix (b) with ** and * indicating significant correlations at the 0.01 and 0.05 levels, respectively. The shading indicates the magnitude of significant correlation values at the 0.01 level, some of which might occur by chance alone.*

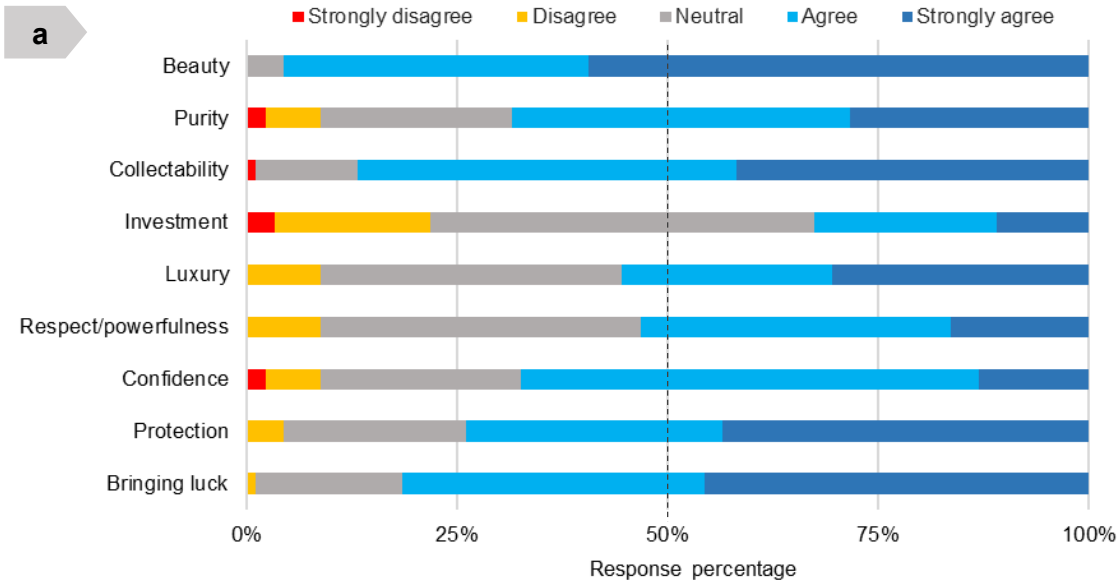
6.3.4 Ivory values and beliefs

The respondents, in general, acknowledged the values and beliefs associated with ivory, except for the investment value yielding median at "Neutral" (*Figure 6.6-a*). Beauty was the most acknowledged value with median of 2 "Strong agree". Users considered that ivory had various supernatural benefits (median 1 "Agree"). Purity, luxury and collectability values also had a median of 1, and the collectability option had the fewest disagreements.

Other interesting beliefs and related opinions provided by respondents included:

- *Positive influence for businesses* [SC12]
- *Ivory is spiritual itself. Making things from ivory by revered monks will enhance spiritual benefits* [SC19]
- *Ivory from killed elephants brings damnation and bad lucks to life. I bought ivory from the shop indicated that ivory in the shop is auspicious because no elephants killed for ivory* [SC85].

The strongest correlation was between protection and bringing luck (correlation coefficient = 0.680, p=<0.001), followed by those between respect/powerfulness and luxury (correlation coefficient = 0.604, p=<0.001) (*Figure 6.6-b*). Among all ivory value/belief views, feelings of confidence and respects/powerfulness had strong relationship with most other variables. For instance, confidence was strongly correlated with respect/powerfulness and investment. Viewing ivory as an investment was significantly correlated with its luxury value. Other positive correlations included beauty and bringing luck, protection and purity, collectability and beauty.



b

	Bringing luck	Protection	Confidence	Respect/ powerfulness	Luxury	Investment	Collectability	Purity
Protection	0.680** < 0.001							
Confidence	0.256* 0.014	0.272** 0.009						
Respect/ powerfulness	0.392** < 0.001	0.333** 0.001	0.552** < 0.001					
Luxury	0.093 0.375	0.118 0.263	0.507** < 0.001	0.604** < 0.001				
Investment	0.201 0.055	0.250* 0.016	0.447** < 0.001	0.430** < 0.001	0.504** < 0.001			
Collectability	0.295** 0.005	0.340** 0.001	0.321** 0.002	0.330** 0.001	0.268* 0.010	0.417** < 0.001		
Purity	0.207* 0.048	0.436** < 0.001	0.074 0.485	0.023 0.826	-0.124 0.239	0.275** 0.008	0.342** 0.001	
Beauty	0.409** < 0.001	0.254* 0.015	0.160 0.129	0.335** 0.001	0.329** 0.001	0.215* 0.041	0.401** < 0.001	0.186 0.077
Value								

Figure 6.6: Ivory value and belief in frequency (a), and the association among the ivory purchasing factors and the statistical test results of association (b).

*The dashed line in a) indicates the median for each factor. Correlation values in b) with ** and * indicate significant correlations at the 0.01 and 0.05 levels, respectively. Dark to light shading indicates the magnitude of significant correlation values at the 0.01 level, with darker shades of blue denoting higher levels of significance. These results should be treated with caution as some significant correlations can occur by chance.*

6.4 Discussion

6.4.1 Factors affecting ivory purchase by ivory shop customers

When looking to purchase ivory in shops, I found customers first prioritized factors related to the shop credentials, followed by the aesthetic attributes of ivory, ivory price, beliefs/values related to ivory, and source. Most Thai ivory consumers are concerned about ivory authenticity, but are unable to separate ivory from bone or other materials; they therefore rely on the seller's guarantee of authenticity (USAID Wildlife Asia, 2018).

Legal reforms and the resultant transaction costs associated with implementing the legal requirements (Chaitae, Gordon, et al., 2022) likely increase the price of legal ivory. In contrast, illegal ivory producers lowered the price of ivory jewellery to reduce competition with the legal market (Moyle & Conrad, 2014). Buying from the illegal market may be cheaper but increases the chance of the buyer purchasing fake items (Hinsley & 't Sas-Rolfes, 2020; Moyle & Conrad, 2014) and thus requires the buyer to have authentication skills.

Ivory sale certificates are issued when buying from authorized shops as evidence of legally-acquired ivory for further registration; some customers are willing to pay more to get products with documentation certifying legitimacy, legality, or provenance (Hinsley & 't Sas-Rolfes, 2020). Such documents also guarantee the authenticity of the ivory. When selecting ivory shops, customer decisions were largely based on trust i.e., recommendation from others, buying from a familiar trader. Buying from an authorized shop likely relieved customer concerns about ivory authentication and legality. Shops with a physical location likely facilitate these perceptions of credibility, as well as enable after-sale service e.g., repairing bought ivory items.

Aesthetic value, or beauty, is considered a very important ivory attribute by Thai ivory customers. Besides the ivory material itself, aesthetic values were likely supplemented by skilful carving and decoration; some ivory jewellery is decorated with gold and gemstones (Krishnasamy et al., 2016). These features increase both the aesthetic and financial values of the items. High aesthetic value in the view of the shop customer was likely related to the nature and use of ivory ornaments, which are the majority of ivory items selling in shops.

Ivory shop customers viewed ivory price as important. The number of possessed ivory items was positively correlated with income, as well as age. Most (80%) of the ivory shop customers, bought their first ivory piece personally, rather than receiving it as a gift or through inheritance. It is, therefore, logical that high income buyers would be able to afford to purchase multiple pieces. Given the strong link between age and income, older people possessed more than 10 ivory items, whereas younger respondents typically owned less than five items. Around one-third of the shop visitors had a monthly income of USD 435 – 870 (15,001 – 30,000 Baht), which was greater than the average income of Thais USD 413 (14,227 Baht) (estimate based on 28,454 Baht /household with two members) (Thailand National Statistical Office, 2021). Purchasing power appeared to affect the type of ivory purchased. Rings, for instance, were the most popular ivory items owned by Thais due to their affordable price (USAID Wildlife Asia, 2018). In this study, necklaces were of most interest to potentials buyers.

Similar to a previous survey (USAID Wildlife Asia, 2018), consumption of ivory in Thailand was largely tied to spiritual beliefs. Most ivory shop buyers believed that ivory brought personal protection and good luck. These beliefs in supernatural properties are also behind the consumption of ivory in Asia more generally (Gao & Clark, 2014; National Geographic and GlobeScan, 2015). For Thais, beliefs related to ivory are typically rooted in the perceived significance of elephants across the dimensions of culture, monarchy, and religion (Chaitae, Gordon, et al., 2022). For example, elephants are believed to be powerful, honourable, and intelligent, thus elephant ivory is likewise considered special and spiritual. Additionally, beliefs linked with sacred items involve faith and respect of revered monks. Uses of ivory products among the public involved sacred items such as lion (singha) figurines, sacred knives with ivory sheath and/or handles) given to believers (Stiles, 2003) by revered monks. The sacred ivory items of the revered monks were thus in demand among believers, particularly items from deceased monks (Chainat privince cultural office & Chainat Pitthayakhom School, N.D.; Nongpho Temple, 2015). This practice potentially leads to such items having increased monetary and collectible values. Different types of spiritual items, such as amulets and sacred figurines are still produced by the main ivory manufacturers in both Surin and Northern provinces (Nakhon Sawan and Uthai Thani) (Suttanon, 2020), even though Buddhist monasteries have been recommended

to avoid making sacred items from ivory and wildlife parts since 2014 (The Sangha Supreme Council of Thailand, 2014).

The purchase of ivory was also linked to its perceived value as an investment, although this factor was weaker for by ivory shop customers in Thailand than in other countries (Gao and Clark 2014). For example, in China, carved art pieces of ivory were highly prized for investment (Gao & Clark, 2014). In contrast, product types in the ivory shops I studied, largely involved small jewellery, which might be less profitable at resale, because its investment potential is limited. Investment purchases are more likely to be focussed on antique sacred items produced by revered monks as discussed above. The resale of such purchases tends to occur between private individuals, rather than through ivory shops. Investment value is potentially high for ivory in form of whole tusks contributed by size and utilization. Knowledge of these variations would provide insights into the demand, as well as enable designing of suitable measures to address the illegal wildlife trade on the basis of culture and other factors (Cheung et al., 2021).

A final significant motivation for purchasing ivory is related to social norms and influence (National Geographic and GlobeScan, 2015; Thomas-Walters et al., 2021). Half the ivory shop respondents agreed that owning ivory was connected with a feeling of luxury. An important factor influencing consumption is thus likely to be the desire to meet others' expectations or social norms (Ajzen, 1991; Miller, 2017). Social norms are well documented influences on consumption of wildlife or wildlife products. For example, success in illegal hunting of large mammals maintained valued social relationships within a community of Ethiopian pastoralists (Tadie & Fischer, 2013). Bird hunting in South China was associated with cultural preferences for recreation (Commerçon et al., 2021). Consumption of high price and rare wildlife products such as rhino horn, shark fin, pangolin meat involves social relationships in Asian culture (Fabinyi, 2012; Shairp et al., 2016; Thomas-Walters et al., 2021).

Understanding the role of social norms in human behaviour could improve the success of behavioural change interventions by taking cultural and social values associated with such behaviours into account (Commerçon et al., 2021). Suitable approaches should be grounded in the theory of planned behaviour in which a behaviour results from interactions

between attitudes (i.e., personal values), subjective norms (i.e., social pressures, expectations of others), and perceived behaviour control (i.e., ability to engage in a behaviour).

I consider that recognizing the impact of legalization on reducing stigma (social value) surrounding illicit consumption and stimulating demand (Fischer, 2004). The legalization of the trade in Thai domestic ivory is unlikely to expand consumption to levels of concern. Given the long history of legal ivory from domesticated elephants in Thailand, the 2015 legal reform, (Chapter 2) is likely to enhance awareness of the links between the illegal ivory trade and elephant conservation and reduce demand. In 2015, 5% of Thais owned ivory. This proportion was reduced to 2% in a 2018 survey (National Geographic & GlobeScan, 2015; USAID Wildlife Asia, 2018). For the wider Thai community, possession of ivory was viewed less favourably as most people considered that ivory consumption was unacceptable and only 10% felt otherwise (USAID Wildlife Asia, 2018).

6.4.2 Behavioural interventions

In the development of behaviour change interventions, it is important to realize perceived connections between these values and include these understanding into relevant conservation policy (Cheung et al., 2021; Commerçon et al., 2021; Davis et al., 2020). Ivory consumption has a long history in Thai culture. Social perceptions around elephant ivory are linked with the extraordinary value placed on elephants, and the legality of domesticated elephant ivory (Chaitae, Gordon, et al., 2022; Chapter 2). Suitable communication messages should avoid any sensitivity in these contexts, and probably focus on consumption from legal sources of ivory. Behavioural change interventions tend to be more effective when individuals are provided with information related to their pre-existing personal interest in the target behaviour (Rothschild, 1999).

Thai ivory consumers' concerns over about possessing killed-elephant ivory might help frame communication. For instance, messages highlighting consumer choice about possessing auspicious ivory from live elephants should be more effective than directly opposing the consumer beliefs. Education activities that seek to reduce the consumption of illegal ivory could link the consumption of illegal ivory with harm to elephants through, for example, aligning legal consumption with the Buddhism precept "refrain from taking

life". A similar strategy has been used to reduce the demand for rhino horn in Viet Nam by incorporating "the Strength of Will" Chi Initiative by promoting the internal strength of individual as the source of success and good fortune, rather than these outcomes being acquired externally from a piece of horn (Offord-Woolley, 2017).

Knowledge of legal provisions and conservation impacts would raise public education overall and positively influence consumer choice, as well as the implementation of the legal requirements e.g., transfer of ivory items between private ivory possessors. Moreover, an increased understanding of the purchasing motivations of target segments of the ivory market would enable more efficient behavioural change interventions (Thomas-Walters et al., 2021). The pre-existing high levels of trust in traders by consumers could be leveraged to facilitate and increase the legality of the ivory trade amongst consumers. The Thai government has already prioritized enforcement of groups of ivory traders (CITES SC70 Doc. 27.4 Annex 21, 2018; Elephant Ivory Act B.E. 2558, 2015); It is important to continue consistent monitoring and comprehensive enforcement to reduce the illegal supply. Together with consumption management efforts (e.g., awareness raising and outreach activities), this would reinforce the effectiveness of the domestic ivory trade controls and ensure implementation of Thailand's commitments to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

6.4.3 Limitations of this study

Ivory consumption is typically driven by spiritual beliefs related to protection and good luck. However, there is probably variation around consumption of different item types, which would contribute to different segments of ivory consumers. Demand consumption is related to several factors including personal constraint, motivation, social influence (Veríssimo et al., 2020). Economic factor plays an important role in ivory consumption. Increasing demand for ivory in Asian markets is related to an increase overall economic growth (Stiles, 2004), Conversely, the decline of ivory name seal consumption was linked to the 1980s economic recession in Japan (Kitade & Toko, 2016). My study finding reflected a positive relationship between ivory consumption and income. Well-off ivory consumers can afford a greater volume of ivory, either in terms of the number or size of pieces. A complete pair of raw ivory tusks is usually purchased for home decoration

(Chaitae, Gordon, et al., 2022). Price of this type of decorative ivory, worth a couple of million Baht, would only be possible for users with high financial resources. Ownership of such large ivory pieces reflects wealth and social image, as well as providing an investment similar to art in China (Gao & Clark, 2014). These social attributes may be more important for users who focus on decorative ivory, in contrast to ivory product consumers who value aesthetics. Worshippers likely purchase in accordance with their faith in revered monks. Thus worshippers favour items made by monks and buy them as collectibles or investments.

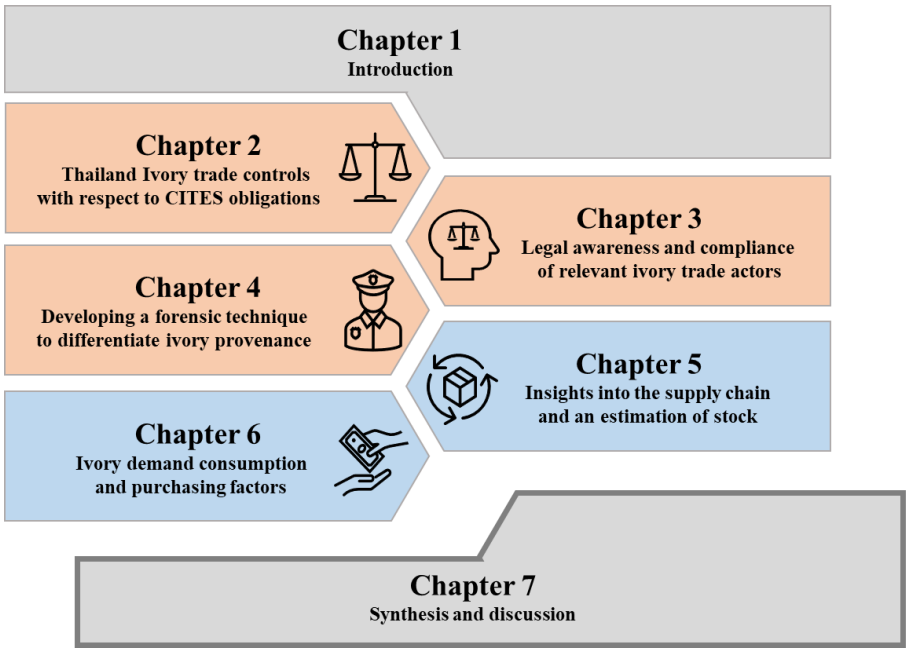
I recognise that sampling bias might have resulted in a sample more orientated towards the legal adherence, given that my sample was collected at authorised ivory shops and government offices. The ivory shop customers I studied were interested in purchasing a wide range of manufactured ivory, such as jewellery and other products, that are typically found in ivory shops (Krishnasamy et al., 2016). I therefore have little information about ivory consumers, who do not source ivory from an ivory shop. More than 80% of the registered ivory in Thailand is raw ivory (intact tusks) (Krishnasamy et al., 2016), potentially sold by non-traders, as evidence for the low interest is such items from the ivory shop customer I sampled. Two-thirds of annual raw ivory volume are in private-held possession of general users (Chapter 5). Similarly, potential consumers of sacred items were not included in this study. I was also unable to study the ivory trade conducted over the internet as I could not obtain a Human Ethics permit for such research.

6.5 Chapter summary

- The legal ivory trade in Thailand operates to satisfy domestic consumption based on local supply. Exploring the attitudes of customers can improve understanding of consumption. This knowledge could give insights into future ivory demand, the risks of an illegal trade, as well as enable tailoring suitable behavioural intervention policy by government.
- In this chapter, I used self-administrated surveys to explore factors influencing ivory consumption amongst ivory shop customers. When purchasing ivory, customers prioritized factors related to shop credentials, followed by the aesthetic attributes of ivory products, ivory price, ivory beliefs, and source of ivory, in order of importance. The decision to visit a particular ivory shop was mostly based on recommendations and personal relationships. The importance of ivory shop credentials to the ivory shop customers presumably links to their concerns about the authenticity and legality of the ivory products. Trust-orientated attitudes of customers could be leveraged to facilitate and increase legal compliance around the ivory trade amongst consumers.
- Ivory shop customers mainly purchase jewellery; raw ivory is less attractive to the customers of ivory shops. Given that most of the legal annual raw ivory supply is in private possession (Chapter 5) and less likely to be purchased from ivory shops (Chapter 6), there are potentially different segments of ivory consumers in Thailand based on their desire for different types of ivory goods. Further in-depth study of this aspect would benefit management (Chapter 7).
- Attitudes to elephant ivory consumption in Thailand are linked to the extraordinary value of Thai elephants, and the legality of domesticated elephant ivory. With these in mind, behavioural change interventions seeking to reduce the consumption of illegal ivory would be more effective if pre-existing beliefs or religious initiatives were incorporated into communication messages. For example, campaigns should take advantage of customer's existing concern around bad power from killed elephant ivory, to encourage legal and sustainable consumption. This also aligns with the Buddhism precept "refrain from taking life", a potentially powerful deterrent when the overwhelming majority of Thais and ivory consumers are Buddhists.

Chapter 7 Synthesis and discussion

This final chapter provides a summary of the outcomes of my thesis. I discuss and synthesize the key findings of my multidisciplinary approach and their management implications, which aim to reinforce the control mechanisms on the Thai ivory market. I finalise the discussion by identifying areas for future research.



7.1 Revisiting the research problems

The unsustainable trade in wildlife and their products has a significant negative impact on the survival of wild populations (Broad et al., 2003; Emslie et al., 2019; Thouless et al., 2016). In contrast, sustainable management can benefit both human economy and wildlife conservation (Biggs et al., 2013; Broad et al., 2003; Delisle et al., 2018; Gordon, 2008). The ivory trade causes global concern regarding the conservation of elephants because of the deliberate slaughter of elephants for their ivory (Thouless et al., 2016). Under CITES, domestic legal markets for ivory are permitted with comprehensive regulations to prevent detrimental impacts on elephants from either elephant poaching or ivory smuggling (CITES Res.Conf. 10.10 (Rev. CoP18), 2019). Nonetheless, countries permitting a legal trade in ivory are still under pressure to close their markets (CITES CoP19 Doc. 66.3, 2022; Collis, 2019; WWF, 2022).

Closing the commercial markets, including domestic markets, is considered by some to be an effective preventive measure to mitigate the negative impacts of the elephant ivory trade (Aryal et al., 2018; CITES CoP17 Doc. 57.2, 2016; Collis, 2019; Dasgupta, 2016; WWF, 2022). In many cases, this stance is advocated without evidence-based information on the supply chain, market and other socioeconomic factors, resulting in unintended consequences (Challender et al., 2019; Cooney & Jepson, 2006). Trade bans directly restrict the quantity of wildlife products coming to market. When demand persists, bans result in a rise in the commercial value of the product, which in turn incentivizes illegal trade, further threatening the survival of traded species (‘t Sas-Rolfes, 2000; Conrad, 2012; Cooney & Jepson, 2006). This effect was evident, for example, in the cases of rhino horn and elephant ivory where overall prices increased after an international trade ban, fuelling poaching in range states (‘t Sas-Rolfes, 2000; CITES CoP19 Doc. 66.5, 2022; Conrad, 2012; Milliken et al., 1993; Wittemyer et al., 2014). Economic opportunities to protect wildlife may diminish and result in ineffective conservation such as reducing the conflict tolerance towards game or hunting trophy species among local communities (Biggs et al., 2013; Rubino & Pienaar, 2020; Weber et al., 2015). Such situations have discouraged Arctic communities from participating in the management of Polar bear (*Ursus maritimus*) (Weber et al., 2015). Hunting restrictions on bushmeat in West Africa during the Ebola virus disease pandemic reduced the sources of income and protein intake of local

communities, pushing the trade underground to meet their subsistence needs (Bonwitt et al., 2018). Delisle et al. (2018) concluded that a traditional hunting ban on dugongs *Dugong dugon* and green turtles *Chelonia mydas* would likely result in the loss of cultural values in Torres Strait Indigenous communities.

Calls for the domestic market in elephant ivory in Thailand to be banned were significant prior to 2015. Lack of comprehensive legal mechanisms for regulating the trade contributed to an illegal trade of ivory within Thailand, and ivory smuggling between Thailand and other countries (CITES CoP16 Doc. 53.2.2 (Rev. 1), 2013). Closure of the Thai domestic ivory market was seen by some as the simplest and most effective method of suppressing the laundering of illegal ivory in the Thai market, thereby avoiding broader sanctions on CITES-listed species, as well as promoting the country's global leadership in ivory trade management (WWF, 2014). The parallel persistence of legal and illegal trading was also believed to cause confusion amongst the public, and necessitate complex monitoring and enforcement (CITES CoP19 Doc. 66.3, 2022).

Despite these calls, Thailand addressed this situation by revising the relevant legislation to empower officials to confiscate African ivory within the country, and strengthen control mechanisms in the use and trade of ivory from Thai domesticated elephants (CITES SC66 Doc. 29 Annex 8, 2015). This decision enabled Thailand to comply with CITES, and to recognise the domestic and wild Asian elephants in Thailand as having a different legal status (Siriphanurak & Thaiwadh, 2015). Trade in the tusks of Thai domesticated elephants is legal in Thailand (Chapter 2), providing an income to elephant owners (Chapter 5). Ivory harvesting can be carried out legally through the practice of elephant keeping. The selling of raw ivory is increasing at present to support elephant owners, particularly elephant owners who are keepers or mahouts, meet the growing costs of living and of raising elephants. Because of this strong economic driver to sell ivory, I believe that a domestic trade ban would likely push the ivory trade underground, increasing the cost of enforcement (*Figure 7.1*). Similar situations have occurred where local communities experiencing economic stress depend on a banned resources (Bonwitt et al., 2018; Koh et al., 2021).

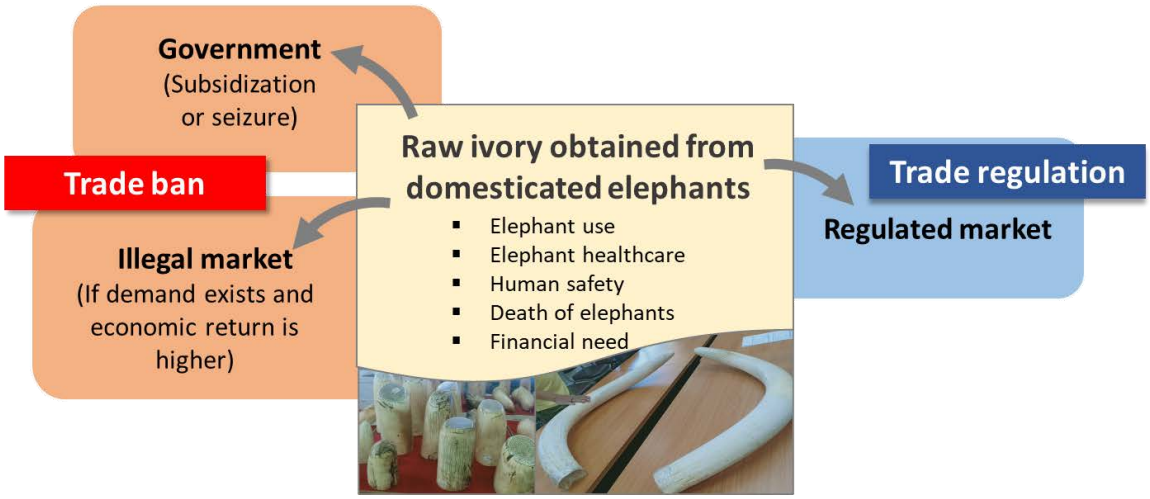


Figure 7.1: Likely contrasting consequences of alternative scenarios for domestic ivory trade management in Thailand*.The figure assumes that: (1) domestic elephant keeping is allowed and raw ivory will continue to be obtained through elephant keeping practices, and (2) the cost of maintaining domestic elephants will continue to be a significant burden for elephant owners.*

Cultural values and history are important factors in determining the suitability of trade bans (Conrad, 2012). A trade ban policy is likely to be successful when consumption does not have social legitimacy (‘t Sas-Rolfes et al., 2019). There is a long history of ivory consumption in Thailand and its link with the lawful ownership of domesticated elephants is rooted in Thai culture (Chaitae, Gordon, et al., 2022). In addition, ivory is considered a price-inelastic, luxury good (Conrad, 2012). This means consumption of ivory is relatively insensitive to price change. Many Asian people buy ivory to help display their social status (Walker, 2009), a conclusion supported by the results in Chapter 6, which provided evidence that the ownership of ivory is motivated by a wish to display luxury and wealth. Although this study suggested that the legality of ivory is important to Thai consumers (Chapter 6), my results might be biased by the fact that my study was limited to customers of legal ivory shops. Users of status goods probably gain social status even when trade in status products is prohibited (TRAFFIC East Asia, 2010). Thus some users are probably willing to risk legal punishment to obtain such products (Conrad, 2012). Moreover, trade restrictions stimulate the desire for ivory as it becomes rarer (Cooney et al., 2015; Hinsley & ‘t Sas-Rolfes, 2020).

Thus, both supply and demand forces likely reduce the success of ivory trade restrictions in Thailand. A total ban is, therefore, unlikely to be an effective solution for managing ivory in Thailand; instead it would likely cause the loss of both natural resources and cultural knowledge (Stiles, 2003). Trade regulation potentially offers a better solution. My research highlights both the need for elephant keepers to trim the tusks of the elephants in their care, and the economic importance of selling ivory for most Thai elephant owners. The domestic trade of ivory in Thailand provides economic and livelihoods benefits to a broad range of actors from elephant owners to shop owners. The effective control of the ivory trade is necessary to maintain this legal market.

To inform improvement in ivory trade controls in Thailand, I addressed Objective 1 of this thesis by: (1) studying the current statutory controls, (2) assessing the legal understanding of the actors in the ivory supply chain, and (3) providing proof of concept for an ivory identification tool (Chapters 2 - 4). I then addressed Objective 2 (to understand the market interactions related to the legal domestic ivory trade in Thailand) by investigating the dimensions of demand and supply of the legal ivory market in Chapters 5 - 6.

My comprehensive findings have the potential to inform the evidence base for a sustainable ivory market in Thailand. This potential should be enhanced by my role as CITES officer the Thai Department of National Parks, Wildlife and Plant Conservation (DNP) as discussed in more detail below.

7.2 Thesis findings

Objective 1: To investigate how control mechanisms relevant to the domestic ivory trade in Thailand could be strengthened

Control mechanisms are necessary for regulating the domestic trade in ivory. In Chapter 2, I assessed legal measures of relevance to regulating the ivory trade under Thai laws. These laws were strengthened in 2015 to enable comprehensive control in compliance with CITES. The existing legislation now enables effective control of the domestic ivory trade as CITES requires. However, the complexity of these laws has resulted in some confusion for lay people around the relevant legislative requirements, as well as high transaction costs to comply with this legal framework.

By exploring the legal awareness of relevant actors in Chapter 3, I found that three groups of actors are generally aware of ivory-related legislation. Ivory traders had a high level of awareness about compliance requirements related to the ivory trade. Legal knowledge was lower amongst groups of elephant owners and ivory consumers, suggesting the need to raise the of awareness of these groups, along with the simplification of relevant laws. All three groups of actors have considerable legal knowledge of the trade prohibitions of ivory from African and wild Asian elephants, as well as international and domestic ivory trade restrictions.

The strong legal awareness of ivory traders was likely, at least partially, to be the result of the enforcement activities that prioritized them. In turn, ivory traders play a key role in raising the legal awareness the other two groups of actors, due to their central position in the supply chain and their trusted role. Personal connections productively facilitate this flow of information. Ivory traders advise elephant owners about the process of raw ivory registration and transfer, increasing the knowledge of elephant owners involved in commercial trade activities e.g., those who sell raw ivory to ivory traders, or reside in ivory manufacturing areas. Whilst doing business, ivory traders also provide legal information to ivory shop customers (users) around the registration of ivory purchased from their shops.

The capacity to prevent the laundering of an illegal supply can enhance the legal market of wildlife products (Biggs et al., 2013). In Chapter 4, I successfully applied the NIRS technique in distinguishing three types of ivory in accordance with Thai laws: African, domesticated Asian, and wild Asian elephant ivory. The translation of this approach has the potential to enable effective monitoring of the domestic market and prevent the entry of illegal supply from African and other Asian elephant sources.

Objective 2: To understand the market interactions related to the legal domestic ivory trade in Thailand.

Ivory harvested from live, domesticated elephants supplies the Thai domestic ivory market. Chapter 5 maps the legal supply chain and identifies the factors influencing the supply that supports the commercial trade. I identified five key actor groups operating in this supply chain: elephant owners, intermediaries, manufacturers, retailers, and ivory consumers. Pre-existing networks of elephant owners facilitate the flow of raw ivory. The legal ivory trade is clearly beneficial to these elephant owners, particularly mahout owners who earn their living from keeping elephants. Nonetheless, market access is not equal among these actors. The sale of tusks is increasing over time, likely due to increased financial pressures on elephant owners and the market factors that increase the price of raw ivory. This chapter also documented the influence of limited legal awareness among elephant owners (Chapter 3), especially owners from outside Surin, for instance, elephant owners dispersedly residing in North and South regions are less known by general buyers of ivory. The annual supply of raw ivory from domesticated elephants is, at least, ~375 kg. Most of this annual supply is either retained by, or goes to, general users for private use, while around one third of this annual volume supplies commercial ivory product manufacturing.

The ivory purchasing of shop customers is influenced by factors related to the trust and credentials of traders; presumably linked to the customers' concerns over the authenticity and legality of the ivory products (Chapter 6). These concerns reflect another important aspect of the traders in the Thai ivory trade, besides awareness raising (Chapter 3). Attitudes informing elephant ivory consumption in Thailand are linked to the extraordinary value of Thai elephants. Ivory shop customers are more interested in purchasing jewellery rather than raw ivory. Given that most of the legal annual raw ivory supply goes directly to private possession (Chapter 5) rather than via ivory shops (Chapter 6), there are potentially different segments of ivory consumers in Thailand based on desire for different types of ivory goods. Other consumer segments may have a different set of attitudes and preferences related to ivory than the actors studied in this thesis.

7.3 Policy and management implications

There are sustainable, legal wildlife trade models internationally from which the Thai ivory trade could learn. The vicuna trade is a successful example of a sustainable wildlife trade achieving mutual benefits for wildlife conservation and human livelihoods (Gordon, 2008; Kasterine & Lichtenstein, 2018) and may be an appropriate exemplar for the domestic trade of ivory in Thailand. Vicuna wool is a high price material used for luxury garments, generating significant revenue to improve the livelihoods and fulfil the economic needs of Andean communities (Kasterine & Lichtenstein, 2018). This economic incentive contributes to the protection of these valuable animals, as well as enabling locals to participate in resource management (Lichtenstein, 2009). Importantly, raw wool is harvested by shearing from live animals offering a sustainable supply to satisfy market demand (Gordon, 2008; Kasterine & Lichtenstein, 2018). This approach is also a potential option for rhino horn in South Africa as the horn of rhinos naturally regrow after dehorning (Biggs et al., 2013; Lindsay & Taylor, 2011).

Nonetheless, the trade in vicuna wool and Thai domesticated elephant ivory differ in important aspects (Chaitae, Gordon, et al., 2022; Chapter 5; Kasterine & Lichtenstein, 2018); for example, the main destinations for vicuna wool are international markets (Kasterine & Lichtenstein, 2018), whereas the Thai ivory market is for domestic uses associated with cultural values. Vicuna wool is sourced from wild, ranched or farmed animals, reflecting the nature of the ownership of animals in different countries (Gordon, 2008). Elephant keeping is primarily for various uses of the animals e.g., tourism, entertainment, and logging. The sale of tusks supplements their basic income. Thai domesticated elephants are owned and cared for by owners who need significant funds to maintain them, in contrast with some vicunas being ranched or free-range, reducing relevant keeping costs, especially food costs. Individual ownership of Thai domestic elephants enables the economic benefit from selling ivory to be earned by their owners; whereas proceeds from the sale of vicuna wool may be shared among a community. There are important similarities too: non-lethal practices can be used to harvest the products from both species i.e., wool of vicunas, ivory tusks of elephants, ensuring the survival of the animals thereby optimizing the economic benefits from exploitation. Ivory is a high value product (Conrad, 2012) capable of providing income to alleviate financial pressure on

elephant owners similar to the way the vicuna wool trade provides income to Andean communities.

Vicuna wool trade symbolizes the possibility of sustainable wildlife trade by demonstrating the capacity of non-lethal harvesting for a high value product to enable long-term use, and providing local communities with an incentive for protecting source animals. Thai ivory trade shares this feature, and I believe that future management should focus on enhancing incentives that are consequences of legal domestic ivory trade, among the relevant actors in wildlife conservation. Based on my research results, I present proposals to strengthen control mechanisms relevant to the domestic ivory trade in Thailand, as well as to promote compliance and engagement to aim a sustainable trade of ivory (*Figure 7.2.*) below.

7.3.1 Simplification of legal requirements

As explained in Chapter 2, the legal controls on the ivory trade in Thailand are complex and likely associated with high transaction costs (Chapters 3 and 5). There are a total of 22 DNP offices for ivory registration. A physical visit to one of these offices often involves significant travel costs for people living outside areas to where these offices are located, especially as DNP offices open only during weekdays. The costs of registering a 500 Baht (*c.*USD15) value small ivory item for a Surin resident at the responsible DNP office in *Ubol Rachathani* could involve a 6-hour return car trip and incur fuel costing at least twice the cost of the ivory item. This estimate does not include the cost of work absence. These costs disincentivize registration.

Simplification of the relevant laws, particularly for regulations stipulated under the Elephant Ivory Act, is likely to facilitate compliance and reduce the transaction costs incurred by physical visits for registration. Unnecessarily complex laws and processes could be reduced for the registration of ivory products bought from authorized ivory shops. This simplification should involve enabling use of ivory sale certificates issued by authorized traders as evidence of legal possession, together with online registration of ivory. Monitoring and enforcement of these processes could be done using existing legal practices e.g., shop records, duplicate copies of sales certificates and relevant inspections of the ivory items being sold in the shop. This simplification could serve the purpose of the

law (Driesen, 2014), whilst reducing transaction costs that arguably burden and disincentivize registrations. This approach could reduce the administrative work for responsible officers, especially with an effective online database, and allow for a greater investment in enforcement and education activities. An assessment of the registration rate of ivory bought from ivory shops can provide information on the outcomes of the legal simplification initiative. Monitoring efficiency and management capacity would also be enhanced as more information becomes available through increasing the rates of ivory registration.

In the long run, the streamlining of relevant regulations, especially those related to the control of animals, and the parts and products of domesticated elephants, into a single law would reduce complication and confusion among relevant actors.

7.3.2 Incentives and engagement of relevant actors

While regulation is an essential tool for a sustainable wildlife trade, incentives are the key to legal compliance (Swanson, 2000). Considering the benefits that relevant actors gain from the laws, elephant owners can sell ivory at higher prices compared to before the 2015 change in the law that relieved concerns around the risk to elephants from ivory smugglers. Ivory traders can maintain their businesses, while ivory consumers are able to use legal ivory without concerns around the illegality of possessed ivory. These potential incentives gained by groups of key actors could be used as strategies to motivate legal compliance.

Benefits from legal wildlife involvement can motivate engagement in conservation by relevant actors (Cooney et al., 2018). Economic revenue incentivizes the conservation of vicuna by maintaining long-term renewable production (Gordon, 2008). Similarly, income from trophy hunting and harvested rhino horns can motivate local communities to protect these valuable animals (Biggs et al., 2013; Lindsey et al., 2012; Rubino & Pienaar, 2020). As demonstrated by these examples, regulation of the Thai ivory trade may not involve direct conservation. However, the engagement of relevant actors and communities can support conservation through enforcement and compliance. Engaging relevant actors and local communities as partners can support enforcement (UNODC, 2020a). For example, the presence of an illegal ivory supply could decrease the volume of ivory bought from elephant owners and/or reduce the price of Thai ivory. Financial benefits for elephant

owners selling ivory can be used as a motivation for reporting suspicious changes. In addition, engaging the general public to report illegal ivory trade incidents via DNP's anti-wildlife crime units may be highly beneficial (CITES SC74 Doc. 39, 2022).

7.3.3 Market monitoring

Analysis of a supply chain provides a comprehensive understanding of the trade and enables the tailoring of appropriate policy responses (Boakye et al., 2016; Cowlishaw et al., 2005; UNODC, 2020b). The accessibility and cost-effectiveness of the legal supply to the market are important factors involved in maintaining a non-detrimental market for wildlife products (Biggs et al., 2013). In Thailand, harvesting the ivory of domestic elephants is necessary both for elephant husbandry and to support the livelihood of elephant owners. Ivory can be harvested non-lethally, a practice that allows for a replenishment of supply until the animal dies naturally. This newly harvested ivory is the main source of ivory supplying ivory product manufacture; however, the significant volume of pre-legislation stock provides a surplus. The first national registration of domesticated elephant ivory in 2015 revealed that c. 160 tons of raw ivory was privately-held in Thailand (Krishnasamy et al., 2016). My study indicates that about 380 kg of raw ivory is obtained annually from domesticated elephants; and around two thirds of this annual production go into private possession while the commercial trade uses about 170 kg of raw ivory, of which newly-obtained ivory is the major source.

The information on the legal supply in Chapter 5 can be used to inform the monitoring of the ivory trade. Monitoring of the supply chain, as well as the trade volume and the market price of the raw ivory will provide useful information about market interactions and the potential entry of illegal stock. In theory, with stable demand, the increased availability of illegal stock should decrease the price of Thai ivory and result in the lowering of the legal supply volume used in manufacturing. Monitoring data should also highlight the proportional change between newly obtained and pre-legislation stocks in manufacturing. For example, increasing volumes of the pre-legislation stocks transferred to manufacturers can indicate market changes e.g., possibility of an increase in demand, decline of annual ivory supply. NIRS devices could potentially be used to validate ivory sources (Chapter 4).

In parallel with monitoring supply, it is vital to understand the demand volume. Thai ivory consumption is not significant in volume and probably in decline: in a 2018 survey 2% of Thais owned ivory products compared with 5% recorded in 2015 (National Geographic & GlobeScan, 2015; USAID Wildlife Asia, 2018). Monitoring demand would also reduce concern around the potential escalation of demand contributed by the legal market. However, consumption needs to be monitored to capture demand that can change through time. Growth in demand could be reflected in an increase in the volume of traded ivory and should be a priority for further investigation. This signal could be caused by an increase in domestic consumption, leakage of ivory to other countries, or both.

In addition, consistent enforcement effort is required to deter illegal activities. Besides monitoring the legal market, it is essential to suppress the illegal trade in physical shops and online channels. The illegal trade can significantly hamper the control of the legal trade by the entry of detrimental ivory stocks to the system violating CITES provisions, as well as discouraging authorized traders' efforts to implement the laws. Comprehensive trade controls should prevent both the entry of illegally sourced ivory into the domestic market and the export of ivory products from the country.

7.3.4 Public education and outreach

Public awareness plays an important role in consumer decision making in purchasing wildlife products (‘t Sas-Rolfes et al., 2019; Hinsley & ‘t Sas-Rolfes, 2020; Liu et al., 2016). Awareness of the ivory trade among Thais seems to be growing since the new laws of 2015, as reflected by ivory shop customers' concerns around the legality of ivory products (Chapters 3 and 6). Conservation and legal information should be continuously provided by government to the public, as is currently done in Thailand (CITES SC74 Doc. 39, 2022). Public education has a significant influence on wildlife consumption choice. For example, by presenting conservation and legal information of related wildlife materials together with lists of substitutions that may provide the same perceived benefit to consumers, traditional medicine customers showed a higher acceptability for substitutions, especially for well-publicized products from endangered species, such as bear bile and tiger bone (Liu et al., 2016). Regular public education on the ivory trade should highlight the relationships between illegal ivory purchase and elephant killing, as this knowledge is

limited among Thai ivory consumers (USAID Wildlife Asia, 2018). In addition, public education should take an advantage of the high level of reverence for elephants among Thais about opposing elephants killing for ivory consumption.

Building a social campaign around wildlife consumption, rooted in Thai culture and history, should be based on understanding the cultural values aligned with consumption (Dang Vu & Nielsen, 2021; Thomas-Walters et al., 2021). Thai ivory consumers place an extraordinary value on Thai elephants, and the legality of the domesticated elephant ivory is an important factor affecting their ivory consumption (Chapter 6). Legality and authentication of ivory products are strong concerns in purchasing decisions (Chapters 3 and 6). Interventions to change behaviour should take advantage of customer beliefs about ivory bringing luck and their concerns around bad power from elephant ivory from slaughtered elephants to encourage legal and sustainable consumption. Ivory from authorized shops comes with a sale certificate confirming its legality, analogous to labels specifying product sources such as geological, eco, and sustainably harvested products (Brayden et al., 2018; Gallastegui, 2002). For example, vicuña cloth and garments are labelled with the source country and verification that the wool has been shorn from live animals (CITES, 2022a). Market-based labelling can increase the value of goods that customers are willing to pay for (Brayden et al., 2018; Hinsley & ‘t Sas-Rolfes, 2020; Tian et al., 2022). Knowledge about the conservation impacts of illegal ivory purchase is essential for customers to reject a cheaper purchase choice of illegal ivory. In addition, an ivory substitution strategy could be useful for consumption influenced by faith towards revered monks by encouraging the use of substitute spiritual items made by monasteries and monks. This approach coincides with the policy implemented in 2014 requiring monks to avoid using wildlife parts, including ivory, in making spiritual items (The Sangha Supreme Council of Thailand, 2014).

Interventions could be more effective using communications media and customised messaging to target audiences (Challender & MacMillan, 2014). For instance, communication could capitalise on established networks of elephant owners particularly via word-of-mouth, and frequent contact authorities, through distributing materials and oral messages via the local offices of the Departments of Provincial Administration and Livestock Development. The current positive perceptions towards the regulation system

amongst elephant owners would be supported through education activities. Most importantly, I stress the potential role of ivory traders in awareness raising. Ivory traders are very important actors in the Thai ivory trade chain, in regards to both legal awareness (Chapter 3) and consumption (Chapter 6). Trust-oriented transactions in the ivory trade, together with the intermediary position of the ivory traders in the ivory supply chain, could enhance management strategies, including awareness raising and compliance enhancement. Traders should be equipped with educational materials to enable them to distribute information opportunistically. Ivory traders also could provide encouragement to ivory buyers for registering bought ivory, especially if the relevant legal procedures were simplified, thereby promoting compliance, and enhancing monitoring. These strategies should be efficient and effective in disseminating ivory-related knowledge to targeted groups of actors.

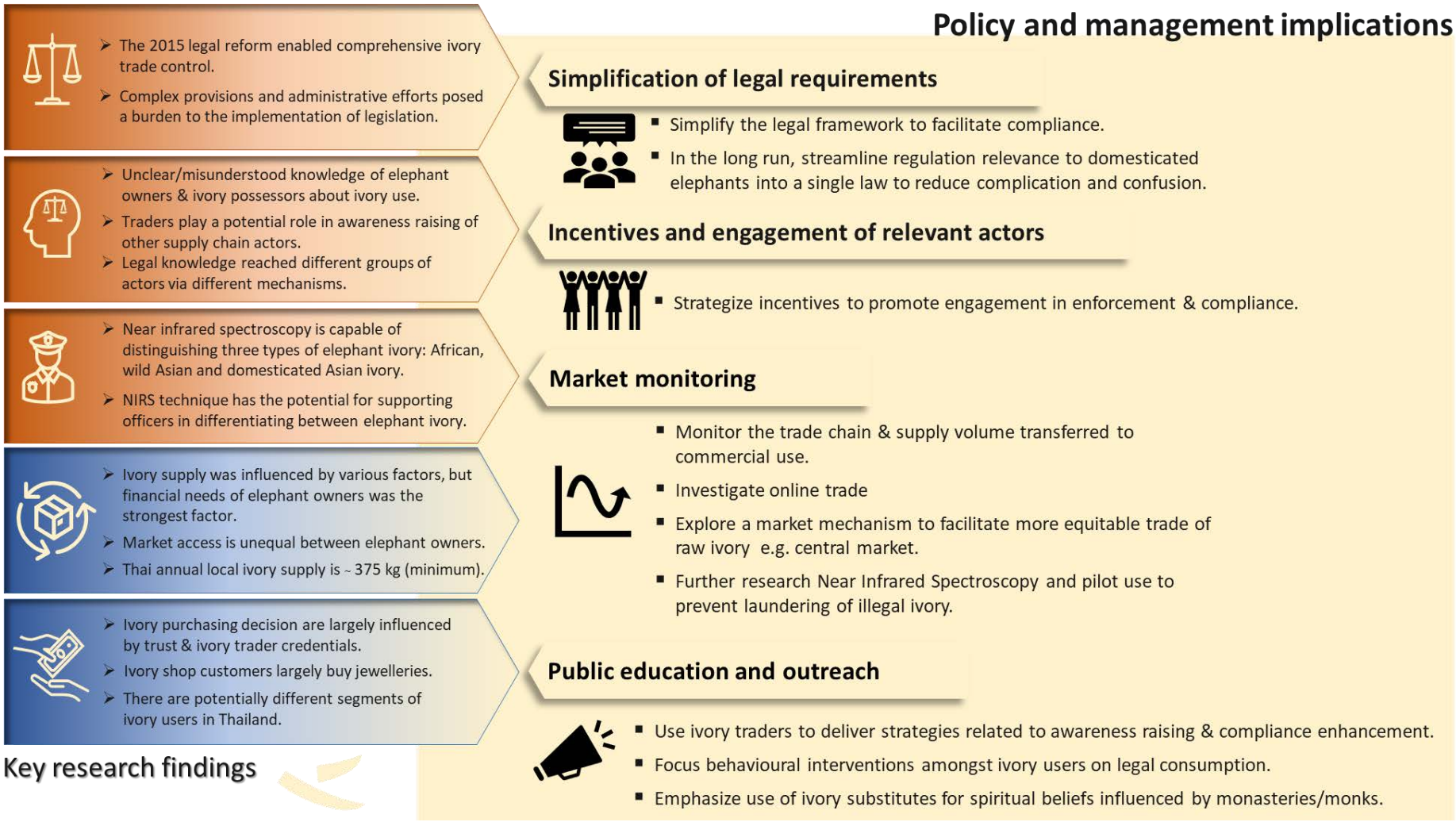


Figure 7.2: Management implications synthesized from research findings.

7.4 Future research

As mentioned in previous chapters, I have identified several further studies that would improve understanding of the Thai ivory trade. Here I prioritize potential future directions of research based on their likely relevance to maintaining a sustainable, legal trade.

Legal compliance can reflect the effectiveness of laws. My Unmatched Count Technique (UCT) study in Chapter 3 was unable to provide a conclusive result around the extent of non-compliance. Recognizing the limitations of this approach, future research should be designed to quantify compliance levels to benefit management. In addition, policy development would benefit from understanding the attitudes of relevant officers and enforcement efficiency as Thai ivory trade control involves cooperation among relevant authorities.

In Chapter 4, I documented the capacity of NIRS devices to differentiate the provenance of ivory, either between African and Asian ivory sources, or between Asian ivory in wild and domesticated elephants. I stress the need for further research to capture variation in ivory among domesticated and wild Asian elephants with diverse feeding regimes and dentine chemistries. The latter will allow comprehensive monitoring of ivory products, which primarily consist of dentine. Use of NIRS devices could also be facilitated by their customization for specific tasks as have been done for other industries, e.g., a commercial NIR portable model has been developed for measuring plant leaf spectroscopy (CID Bio-Science, 2022). A local inventor developed an NIR method and network system for online and offline measurement of qualities of cup lump rubber (Rittiron, 2017).

Online platforms (such as social media) offer a convenient way for consumers to access illegal sources of wildlife products, and have become a significant challenge to enforcement (UNODC, 2020a). I agree with the concerns of Indraswari et al. (2020) and Krishnasamy et al. (2016) about the growth in an online ivory trade after the introduction of the 2015 restrictions on the ivory trade stores; an illegal trade of ivory could lead to the closure of the Thai ivory trade (CITES Res.Conf. 10.10 (Rev. CoP18), 2019), with subsequent negative consequences for the livelihoods of relevant groups of actors. Unfortunately, whilst I recognise the importance of online trade monitoring, particularly on

social media platforms, I was unable to conduct this research because I could not obtain the necessary Human Ethics approvals from James Cook University. Internet trade research could provide insights into characteristics and context of illegal activities that can inform future enforcement for combatting this challenge.

At present, Thai domestic ivory trade provides important financial support for elephant owners in terms of either contributing to household living costs, or for the cost of elephant keeping, as well for maintaining a livelihood for other relevant actors. As evident from Chapter 5, this trade of ivory mainly is operated by individuals i.e., raw ivory is sold by individual elephant keepers/owners. Inequitable access to the market by elephant owners is likely due to elephant owners residing in areas other than Surin, the well-known home of elephants (Chapter 5). The limited market access of some elephant owners disadvantages them in price negotiations. Identification and development of appropriate mechanisms for allowing a more equitable trade of raw ivory could help maintain the price and value of legal ivory. Economic incentives could encourage the registration of raw ivory in a way that benefits compliance. For example, a central market structure has been used in Thailand for agriculture products, such as rubber, food produces, to facilitate the trade between seller and buyers (Thailand's Department of Internal Trade, 2022). A similar arrangement may make the domestic ivory trade more equitable.

My research focuses on the legal trade and my findings are restricted to aspects of this trade, particularly the compliance of ivory possessors (Chapter 3) and attitudes of ivory shop customers (Chapter 6). Interpretation of these results should be made with caution. Additional research could provide further insights into aspects of the trade that were not fully covered in this study; for example, trade and consumption of raw ivory, spiritual items made from ivory, legal knowledge of ivory consumer in national level, as well as a long-term study of supply from Thai domesticated elephants.

7.5 Concluding remarks

The Thai ivory trade is based on a renewable supply from legal Thai domesticated elephants. This ivory provides important income to elephant owners, who often have an unstable financial status. The trade maintains cultural knowledge of ivory carving and creates licit earnings in local communities for relevant groups of actors in the supply chain. I agreed with Stiles (2003) that an ivory trade ban is not an appropriate solution for Thailand at this time, as it could result in loss of cultural knowledge and natural resources. Like other legal wildlife trades, trade in ivory can be managed sustainability; ivory trade policy should be nuanced, and comprehensive to enable it to benefit people in a sustainable manner. I believe that my research has the potential to contribute to evidence-based policy that ensures that the Thai domestic ivory trade is sustainable.

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Appendix

Supplemenatry information for Chapter 2

Table S2.1: *National laws with direct provisions in relevant to elephants and ivory in Thailand*

Legislation	Summary of purposes and related provisions	Authorities
1. Wild Elephant Protection Act B.E. 2464 (1921)	The first version of this law was issued in 1900. The act specifically granted protection to wild elephants as under ancient royal tradition and laws. As wild elephants are deemed government property, capturing them requires government permission. The provisions are mainly related to regulation for capturing and protecting elephants from harm or slaughter, as well as defining the characteristic of auspicious elephants, and procedures related to auspicious elephants (Pravorapakpibul, 1962; Wild Elephant Protection Act B.E. 2464, 1921).	Department of Provincial Administration, Ministry of Interior
2. Draught Animals Act (*Beasts of Burden Act*) B.E. 2472 (1939)	This act was issued to protect the ownership rights of draught animals (working livestock) i.e., elephants, horses, cattle, buffaloes, mules and donkeys, which are considered as an asset. Registered animals have identification documentation consisting of owner and animal information. Changes in any physical characteristics and death of the animals need to be reported for inspection, correction, and revocation (dead animal) of the documentation (Draught Animals Act B.E. 2482, 1939). The elephant has been defined as a draught animal since the first Draught Animals Act R.E. 110 (1891). However, the use of identification documents for elephants had been employed since 1877 under the Buffalo and Cattle Act, which was replaced by the Draught Animals Act (Pravorapakpibul, 1961; 1962). The Draught Animals Act B.E. 2482 (1939) requires each domesticated elephant to be registered when it is eight years old to obtain an identification document describing its physical characteristics and owner details. Elephant owners have to report changes in any physical characteristics of a domesticated elephant, including tusk trimming changes to tusk size, and the death of an elephant (may result in obtaining whole tusks). The registrar of this law administratively issues a certificate of origin for elephant ivory as evidence of legal ivory acquisition.	

Table S2.1: *National laws with direct provisions in relevant to elephants and ivory in Thailand (Cont.)*

Legislation	Summary of purposes and related provisions	Authorities
3. Elephant Ivory Act B.E. 2558 (2015)	This law governs the uses of elephant ivory sourced from domesticated elephants registered under the Draught Animals Act B.E. 2472 (1939) and their offspring (Elephant Ivory Act B.E. 2558, 2015). Provisions cover possession, registration, trade control, and import and export control of domesticated elephant ivory. Registration of ivory possession requires presentation of the certificate of origin for elephant ivory. For the ivory trade, in particular, ivory traders have record-keeping obligations under this law (i.e., ivory acquisition, manufacturing, trade), and are required to provide buyers with the ivory sales certificate as evidence for possession of the relevant registrations (Ministerial Regulation on application, permission, trade and suspension or revocation of ivory trade permit B.E. 2558, 2015).	Department of National Parks, Wildlife and Plant Conservation, Ministry of Natural Resources and Environment
4. Wild Animal Reservation and Protection Act B.E. 2562 (2019) - WARPA	WARPA is the main law for wildlife conservation in Thailand. This act provides protection for animal species and wildlife habitats from difference activities of exploitation. For animal protection, provisions related to hunting, breeding, possession, trade, as well as the import and export of live and dead specimens of species under the control e.g., reserved animal, protected animals (WARPA B.E. 2562, 2019). As a wildlife species, the wild Asian elephant receives full protection in protected areas since the enactment of the first WARPA in 1960 (WARPA B.E. 2503, 1960). The wild Asian elephant was first listed as a protected animal under WARPA 1960 in 1975 (Ministerial Regulation No. 10 (B.E. 2518) issued under WARPA B.E. 2503, 1975), where exploitation was partly allowable (e.g., live capture, two-elephant possession limit) (Announcement of the National Executive Council No. 228, 1972; Ministerial Notification on prescribing possession limit of protected animals according to WARPA B.E. 2503, 1976).	

Table S2.1: *National laws with direct provisions in relevant to elephants and ivory in Thailand (Cont.)*

Legislation	Summary of purposes and related provisions	Authorities
	Complete protection was granted to wild Asian elephants from commercial use upon the updated WARPA 1992 (WARPA B.E. 2535, 1992; Ministerial Regulation No. 4 (B.E. 2537) issuing under WARPA B.E. 2535, 1994). The African elephant was included in category of protected animals in 2015 (Ministerial Regulation on prescribing protected animals (No. 3) B.E. 2558, 2015). Both wild Asian and African elephants currently remain under the protection of the new WARPA as protected animals, and are completely protected from commercial use either live or dead specimens, including their ivory and other parts (WARPA B.E. 2562, 2019).	
5. Commercial Registration Act B.E. 2499 (1956)	The Commercial Registration Act (1956) was designed to compile statistical information on specific businesses to enable appropriate monitoring and control measures. Ivory-related businesses (manufacturers, retailers and wholesalers) are required to register their business with the Department of Business Development (Notification of the Ministry of Commerce on registration requirement of businesses (No. 8) B.E. 2547, 2004).	Department of Business Development, Ministry of Commerce
6. Accounting Act B.E. 2547 (2000)	This law generally applies to companies and other legal entities, as well as certain types of businesses, that are needed to keep accounts in relation to trade and finance. Ivory-related entrepreneurs are required to do bookkeeping their ivory trade activities and keep the records (Notification of Ministry of Commerce on prescribing the duty of accounts maintenance for ivory-related entrepreneurs B.E. 2551, 2008).	

Table S2.1: *National laws with direct provisions in relevant to elephants and ivory in Thailand (Cont.)*

Legislation	Summary of purposes and related provisions	Authorities
7. Animal Epidemics Act B.E. 2558 (2015)	Control mechanisms are designed to prevent and control animal epidemics, including permit required for trade, movement, and export and import of various groups animals in both live and carcasses. Elephants are animals under control of this law. The import and export, domestic trade, and inter-provincial movement of raw elephant ivory requires formal permission (Animal Epidemics Act B.E. 2558, 2015).	Department of Livestock Development, Ministry of Agriculture and Cooperatives
8. Export and Import of Goods Act B.E. 2522 (1979)	This act aims to control the international trade of particular goods for different purposes, for example, economic stability, public health, national security. Asian elephants, their parts and products are prescribed as goods requiring permission to export under this law (Notification of the Ministry of Commerce on specifying elephant as a goods required a license prior to export B.E. 2555, 2012).	Department of Foreign Trade, Ministry of Commerce
9. Customs Act B.E. 2560 (2017)	The act applies to import and export of goods into/out of Thailand, or transit through the country. Both African and Asian elephants, including parts and products thereof, are protected under relevant laws e.g., valid import/export permits are required. Thus the Customs Act is applicable to export, import and transit of all elephant specimens as restricted goods (Customs Act B.E. 2560, 2017).	Royal Thai Customs, Ministry of Finance

Supplementary information for Chapter 3

Info S3.1: *Interview information and questions used for collecting data from elephant owners and ivory traders*

PROJECT TITLE: The elephant ivory trade in Thailand: Demand, supply and control

Interview name: Ivory harvesting and use

Participant: Elephant owners and middlemen

INTERVIEW INFORMATION SHEET

You are invited to take part in a project that is studying the elephant ivory trade in Thailand. The study is being conducted by Apinya Chaitae as part of her Doctor of Philosophy degree in Agriculture, Environmental and Related Studies at James Cook University, Australia.

If you agree to be involved in the study, you will be asked to participate in a semi-structured interview. The interview, with your consent, will be audio-taped, and should take about 45-60 minutes of your time. We will not disclose your identity. The interview will be conducted at a venue of your choice (e.g. office, ivory shop, temple), or via video-conferencing (e.g., Skype) or phone call (the exact venue/mode will be discussed and confirmed prior to the interview).

Key points for discussion include:

- Elephant ivory harvesting
- Use of harvested ivory
- Flow of harvested ivory into market
- Your general understanding on ivory-related legislation

Taking part in this study is voluntary and you can end your participation at any time without explanation or prejudice. There are no foreseeable risks to you by participating in this research project. Your responses and contact details will be strictly confidential. The data from the study will be used in research publications and Apinya's doctoral thesis (dissertation) entitled "Sustainability of the elephant ivory trade in Thailand: Demand, supply and control", and report to Thai government. You will not be identified in any way in these publications.

If you have any questions about the study, please contact -

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Phone:
Email: helene.marsh@jcu.edu.au

If you have any concerns regarding the ethical conduct of the study, please contact: Human Ethics, Research Office, James Cook University, Townsville, Qld, 4811 Phone: (07) 4781 5011 (ethics@jcu.edu.au)

INTERVIEW QUESTIONS

Introduction

- Tell me a little bit about yourself
- Tell me about your elephants and how you use them? *(Addition for elephant owners)*
- How did you get involve in selling ivory? *(Addition for Middlemen)*

Understanding ivory harvesting

- What are your reasons for harvesting ivory? *(Addition for elephant owners)*
- How do you harvest the ivory? From how many elephants? *(Addition for elephant owners)*

Uses of harvested ivory

- How would you describe ivory (What are your beliefs about ivory)?
- How do you use harvested tusks (sell, keep etc)? How do your practices compare with those of other elephant owners? What do they do with the tusks from their elephants? How does this compare with elephant owners in earlier times? *(Addition for elephant owners)*
- How do you sell harvested tusks?
- Who are your ivory buyers?
- What are the raw ivory prices? How you establish the price?
- How often you sell harvested ivory in a one- year period? When was the last time you sold ivory? *(Addition for Middlemen)*

Legal knowledge

- What are you legally required to do to own harvested ivory? And to transfer ownership of ivory to others?
- How do the new laws affect users of ivory?
- How did you learn about new laws? And what is your opinion about it?

PROJECT TITLE: The elephant ivory trade in Thailand: demand, supply and control

Interview name: Raw material supply and ivory manufacturing

Participant: Ivory traders and/or carvers

INTERVIEW INFORMATION SHEET

You are invited to take part in a project that is studying the elephant ivory trade in Thailand. The study is being conducted by Apinya Chaitae as part of her Doctor of Philosophy degree in Agriculture, Environmental and Related Studies at James Cook University, Australia.

If you agree to be involved in the study, you will be asked to participate in a semi-structured interview. The interview, with your consent, will be audio-taped, and should take about 45-60 minutes of your time. We will not disclose your identity. The interview will be conducted at a venue of your choice (e.g. office, ivory shop, temple), or via video-conferencing (e.g., Skype) or phone call (the exact venue/mode will be discussed and confirmed prior to the interview).

Key points for discussion include:

- Your sources of raw ivory, and criteria for ivory purchasing
- Your understanding of the flow of raw ivory to manufacturing process
- The behavior of ivory users
- Attitude of relevant stakeholders to ivory and related legislation
- Your general understanding on ivory-related legislation

Taking part in this study is voluntary and you can end your participation at any time without explanation or prejudice. There are no foreseeable risks to you by participating in this research project. Your responses and contact details will be strictly confidential. The data from the study will be used in research publications and Apinya's doctoral thesis (dissertation) entitled "Sustainability of the elephant ivory trade in Thailand: Demand, supply and control", and reports to Thai government. You will not be identified in any way in these publications.

If you have any questions about the study, please contact -

Principal Investigator:
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Email: Apinya.chaitae@my.jcu.edu.au

Supervisor:
Helene Marsh
College of Science and Engineering
James Cook University
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Email: helene.marsh@jcu.edu.au

If you have any concerns regarding the ethical conduct of the study, please contact: Human Ethics, Research Office, James Cook University, Townsville, Qld, 4811 Phone: (07) 4781 5011 (ethics@jcu.edu.au)

INTERVIEW QUESTIONS

Introduction

- Tell me a little bit about yourself and your position here.
- How did this ivory trade/carving start?
- How would you describe ivory (What are your beliefs about ivory)?

Raw material and manufacturing

- How you get the raw ivory you need, from whom? (*Addition to ivory traders*)
- What criteria and quality do you have for ivory purchasing? What are the prices of raw ivory? (*Addition to ivory traders*)
- Have you been able to access the raw material you need and if not how can you deal with this problem? (*Addition to ivory traders*)
- Please tell me about process of ivory product manufacturing/carving?
- Can you able to differentiate types of ivory (e.g. Asian wild, Asian domestic and African ivory), and how?
- Do you have any criteria for accepting an ivory manufacturing/carving job, and what are the criteria and why?

Ivory consumption behaviour

- What did your customers tell you about their use of ivory?
- In your experience, how has ivory consumption/use changed in Thailand in recent years?
- What are the common questions/concerns raised by customers about buying ivory? How do you respond to these queries? (*Addition to ivory traders*)

Legal knowledge

- Do you tell your customers about ivory registration, and what do you tell them? (*Addition to ivory traders*)
- What is your legal understanding about ivory possession, manufacturing (carving) and trade?

Legislation effect

- What do you know about the 2015 ivory-related legislation reforms? What is your opinion about it, and How do these reforms affect your business plan?
- How helpful do you find the support from government officers in your efforts to implement the law properly?

Thai translation

โครงการวิจัย: การค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม

หัวข้อการสัมภาษณ์: การตัดงาช้างและการใช้ประโยชน์

ผู้ให้สัมภาษณ์: เจ้าของช้าง และ/หรือ พ่อค้าคนกลาง

เอกสารข้อมูลการสัมภาษณ์

ขอเชิญท่านเข้าร่วมการในโครงการวิจัยเกี่ยวกับการคางาช้างในประเทศไทย ซึ่งดำเนินการวิจัยโดยนางสาว อภิญญา ใจแท้ เป็นส่วนหนึ่งของวิทยานิพนธ์ระดับปริญญาเอกในสาขาเกษตรกรรม สิ่งแวดล้อม และการศึกษาที่เกี่ยวข้อง ณ มหาวิทยาลัยเจมส์คุก ประเทศออสเตรเลีย

หากท่านตอบรับเข้าร่วมการศึกษานี้ ท่านจะถูกสัมภาษณ์ด้วยคำถามกึ่งโครงสร้างใช้ระยะเวลาประมาณ 45-60 นาที โดยจะมีการบันทึกบทสัมภาษณ์ โดยที่ท่านให้ความยินยอม ทั้งนี้จะไม่มีการเปิดเผยข้อมูลระบุตัวตนของท่าน และจะดำเนินการสัมภาษณ์ ณ สถานที่ที่ท่านระบุ หรือ ผ่านทางระบบ video-conferencing (เช่น Skype) หรือทางโทรศัพท์ ทั้งนี้สถานที่หรือวิธีการสัมภาษณ์จะได้ประสานงานเพื่อยืนยันก่อนการสัมภาษณ์
ประเด็นการสนทนาประกอบด้วย

- การใช้ประโยชน์งาช้าง
- แหล่งที่มาของงาช้างดิบ และเกณฑ์ในการเลือกซื้องาช้าง
- ความเชื่อและความศักดิ์สิทธิ์ของงาช้าง
- ความเข้าใจทั่วไปเกี่ยวกับกฎหมายที่เกี่ยวข้องกับงาช้าง

การเข้าร่วมของท่านเป็นการสมัครใจ โดยท่านสามารถหยุดการให้สัมภาษณ์ได้ตลอดเวลาโดยมิต้องอธิบายหรือเหตุผลแต่อย่างใด การให้สัมภาษณ์นี้จะไม่มีความเสี่ยงที่สามารถคาดคะเนได้ การให้สัมภาษณ์และรายละเอียดติดต่อของท่านจะเป็นความลับ โดยข้อมูลที่ได้จะใช้ในการตีพิมพ์งานวิจัยและวิทยานิพนธ์ระดับปริญญาเอก เรื่อง ความยั่งยืนของการค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม และรายงานเสนอกรมอุทยานแห่งชาติ สัตว์ป่า และพันธุ์พืช โดยจะไม่มีการระบุตัวตนของท่านในสิ่งพิมพ์เหล่านี้แต่อย่างใด

หากท่านมีข้อสงสัยเกี่ยวกับการดำเนินงานวิจัย โปรดติดต่อ

นักวิจัย:	**อาจารย์ที่ปรึกษา:**
อภิญญา ใจแท้	เฮเลน มาร์ช
คณะวิทยาศาสตร์และวิศวกรรมศาสตร์	คณะวิทยาศาสตร์และวิศวกรรมศาสตร์
มหาวิทยาลัยเจมส์คุก	มหาวิทยาลัยเจมส์คุก
โทร:	โทร:
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หากท่านมีข้อกังวลเกี่ยวกับข้อกำหนดด้านจริยธรรม โปรดติดต่อ ส่วนจริยธรรมงานวิจัยในมนุษย์ สำนักงานวิจัย มหาวิทยาลัยเจมส์คุก เมืองทาวส์วิว รัฐควีนส์แลนด์ *4811* โทร *(07) 4781 5011 (ethics@jcu.edu.au)*

คำถามสำหรับการสัมภาษณ์

การแนะนำตัวเอง

- เล่าให้ฟังเกี่ยวกับตัวท่าน
- เล่าให้ฟังเกี่ยวกับช้างของท่านและการใช้งานช้าง (เพิ่มเติมสำหรับเจ้าของช้าง)
- ท่านเข้ามาเกี่ยวข้องกับการค้าขายงาช้างได้อย่างไร (เพิ่มเติมสำหรับพ่อค้าคนกลาง)

ความเข้าใจเกี่ยวกับการตัดงาช้าง

- เหตุผลที่ท่านตัดงาช้างคืออะไร (เพิ่มเติมสำหรับเจ้าของช้าง)
- ท่านตัดงาช้างอย่างไร ตัดมาแล้วกี่เชือก (เพิ่มเติมสำหรับเจ้าของช้าง)

การใช้ประโยชน์งาช้างที่ตัดมา

- ท่านมีความเชื่อเกี่ยวกับงาช้างอย่างไรบ้าง
- ท่านใช้ประโยชน์งาช้างที่ตัดมาอย่างไรบ้าง (ขาย, เก็บ อื่นๆ) เหมือนหรือต่างจากเจ้าของช้างคนอื่นๆ อย่างไรบ้าง เขาทำอย่างไรกับงาช้างของพวกเขา แล้วเจ้าของช้างในอดีตที่ผ่านมาใช้งาช้างที่ตัดมาอย่างไร (เพิ่มเติมสำหรับเจ้าของช้าง)
- ขายงาช้างที่ตัดมาอย่างไร ใครมาซื้อ
- ขายอย่างไร มีเกณฑ์การตั้งราคาอย่างไรบ้าง
- ตัดงาช้างบ่อยแค่ไหนในแต่ละปี ขายงาช้างครั้งสุดท้ายเมื่อไหร่ (เพิ่มเติมสำหรับพ่อค้าคนกลาง)

ความรู้เกี่ยวกับกฎหมาย

- ต้องทำอย่างไรบ้างตามกฎหมายหากจะตัดงาช้าง และหากจะโอนให้กับผู้อื่น
- กฎหมายใหม่ส่งผลกระทบต่อการใช้ประโยชน์งาช้างอย่างไรบ้าง
- ท่านทราบเกี่ยวกับกฎหมายใหม่ได้อย่างไร และท่านมีความคิดเห็นอย่างไรบ้าง

โครงการวิจัย: การค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม

หัวข้อการสัมภาษณ์: งาช้างดิบและการแปรรูปงาช้าง

ผู้ให้สัมภาษณ์: ผู้ค้างาช้าง และ/หรือ ช่างแกะสลัก

เอกสารข้อมูลการสัมภาษณ์

ขอเชิญท่านเข้าร่วมการในโครงการวิจัยเกี่ยวกับการดางาช้างในประเทศไทย ซึ่งดำเนินการวิจัยโดย นางสาวอภิญญา ใจแท้ โดยเป็นแท้ เป็นส่วนหนึ่งของวิทยานิพนธ์ระดับปริญญาเอกในสาขาเกษตรกรรม สิ่งแวดล้อม และการศึกษาที่เกี่ยวข้อง ณ มหาวิทยาลัยเจมส์คุก ประเทศออสเตรเลีย

หากท่านตอบรับเข้าร่วมการศึกษาในครั้งนี้ ท่านจะถูกสัมภาษณ์ด้วยคำถามกึ่งโครงสร้างใช้ระยะเวลาประมาณ 45-60 นาที โดยจะมีการบันทึกบทสัมภาษณ์ โดยที่ท่านให้ความยินยอม ทั้งนี้จะไม่มีการเปิดเผยข้อมูลระบุตัวตนของท่าน และจะสัมภาษณ์ ณ สถานที่ที่ท่านระบุ หรือผ่านทางระบบ video-conferencing (เช่น Skype) หรือ ทางโทรศัพท์ ทั้งนี้จะได้ประสานงานยืนยันสถานที่หรือวิธีการสัมภาษณ์ก่อนการสัมภาษณ์

ประเด็นการสนทนาประกอบด้วย

- แหล่งที่มาของงาช้างดิบ และเกณฑ์ในการเลือกซื้องาช้าง
- การนำงาดิบเข้าสู่กระบวนการแปรรูป
- พฤติกรรมของผู้ใช้งาช้าง
- ทัศนคติของผู้มีส่วนได้ส่วนเสียในการค้างาช้างต่อกฎหมายที่เกี่ยวข้อง
- ความเข้าใจทั่วไปเกี่ยวกับกฎหมายที่เกี่ยวข้องกับงาช้าง

การเข้าร่วมของท่านเป็นการสมัครใจ โดยท่านสามารถหยุดการให้สัมภาษณ์ได้ตลอดเวลาโดยมิต้องอธิบายหรือเหตุผลแต่อย่างใด การให้สัมภาษณ์นี้จะไม่มีความเสี่ยงที่สามารถคาดคะเนได้ การให้สัมภาษณ์และรายละเอียดติดต่อของท่านจะเป็นความลับ โดยข้อมูลที่ได้จะใช้ในการตีพิมพ์งานวิจัยและวิทยานิพนธ์ระดับปริญญาเอก เรื่อง ความยั่งยืนของการค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม และรายงานเสนอกรมอุทยานแห่งชาติ สัตว์ป่า และพันธุ์พืช โดยจะไม่มีการระบุตัวตนของท่านในสิ่งพิมพ์เหล่านี้แต่อย่างใด

หากท่านมีข้อสงสัยเกี่ยวกับการดำเนินงานวิจัย โปรดติดต่อ

นักวิจัย:
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คำถามสำหรับการสัมภาษณ์

การแนะนำตัวเอง

- เล่าให้ฟังเกี่ยวกับตัวท่านและหน้าที่ความรับผิดชอบของท่านที่นี่
- ท่านเริ่มทำการค้าขายงาช้าง/การแกะสลักงาช้างได้อย่างไร
- ท่านมีความเชื่อเกี่ยวกับงาช้างอย่างไรบ้าง

วัตถุดิบและการแปรรูป

- ท่านหางาช้างวัตถุดิบมาได้อย่างไร จากใคร (เพิ่มเติมสำหรับผู้ค้า)
- มีเกณฑ์และคุณภาพในการเลือกงาช้างอย่างไร ราคาเท่าไหร่ (เพิ่มเติมสำหรับผู้ค้า)
- ท่านสามารถหางาช้างดิบได้ตามที่ต้องการหรือไม่ ถ้าไม่ ท่านแก้ปัญหานั้นอย่างไร (เพิ่มเติมสำหรับผู้ค้า)
- โปรดเล่าถึงกระบวนการแปรรูปหรือแกะสลักงาช้าง
- ท่านสามารถแยกงาช้างแต่ละประเภทหรือไม่ อย่างไร
- ท่านมีเกณฑ์ในการรับงานผลิตหรืองานแกะสลักหรือไม่ อย่างไร และมีเหตุผลใดในการกำหนดเกณฑ์ดังกล่าว

พฤติกรรมการบริโภคงาช้าง

- ผู้ซื้องาช้างบอกท่านเกี่ยวกับการใช้ประโยชน์งาช้างของพวกเขาอย่างไรบ้าง
- จากประสบการณ์ของท่าน การบริโภคหรือการใช้ประโยชน์งาช้างเปลี่ยนไปอย่างไรบ้างในช่วงไม่กี่ปีที่ผ่านมา
- คำถามหรือข้อกังวลอะไรของลูกค้าในการซื้องาช้างอย่างไรบ้าง และท่านตอบสนองต่อข้อซักถามนั้นอย่างไร (เพิ่มเติมสำหรับผู้ค้า)

ความรู้เกี่ยวกับกฎหมาย

- ท่านบอกลูกค้าเกี่ยวกับการขึ้นทะเบียนงาช้างหรือไม่ อย่างไร (เพิ่มเติมสำหรับผู้ค้า)
- ท่านมีความเข้าใจเกี่ยวกับกฎหมายอย่างไรเกี่ยวกับการครอบครองงาช้าง การแปรรูป และการค้างาช้างอย่างไรบ้าง

ผลกระทบจากกฎหมาย

- ท่านทราบเกี่ยวกับการปรับปรุงกฎหมายเกี่ยวกับงาช้างใน พ.ศ. 2558 หรือไม่ ท่านมีความคิดเห็นอย่างไรบ้าง และการเปลี่ยนแปลงกฎหมายดังกล่าวส่งผลต่อแผนการทำธุรกิจของท่านอย่างไรบ้าง
- ท่านคิดว่าเจ้าหน้าที่รัฐมีช่วยเหลือสนับสนุนให้ท่านสามารถปฏิบัติตามกฎหมายได้อย่างถูกต้องแค่ไหน

Info S3.2: *Survey used for collecting data from Bangkok ivory possessers (ivory consumers)*

PROJECT TITLE: Assessment of compliance extent among ivory possessors

Survey name: Ivory use and legal understanding

Participant: Ivory possessors

SURVEY INFORMATION SHEET

You are invited to take part in a project that is studying the elephant ivory trade in Thailand. The study is being conducted by Apinya Chaitae as part of her Doctor of Philosophy degree in Agriculture, Environmental and Related Studies at James Cook University, Australia.

If you agree to be involved in the study, you will be asked to complete a three-part survey. The first two parts aims to explore general legal understanding, background and ivory use behaviour, while the last part comprise of demographic questions. The survey should take about 10 minutes of your time. We will not disclose your identity.

Taking part in this study is voluntary and you can end your participation at any time without explanation or prejudice. There are no foreseeable risks to you by participating in this research project. Your responses and contact details will be strictly anonymous. The data from the study will be used in research publications, seminars, Apinya's doctoral thesis (dissertation) entitled "Sustainability of the elephant ivory trade in Thailand: demand, supply and control", and reports to Thai government. You will not be identified in any way in these publications.

Please return the completed survey using stamped envelope attached herewith, and do not write your name and contact details. You could post the letter at any street-posting box or post office for free of charge.

If you have any questions about the study, please contact -

Principal Investigator:
Apinya Chaitae
College of Science and Engineering
James Cook University
Phone:
Email: Apinya.chaitae@my.jcu.edu.au

Supervisor:
Helene Marsh
College of Science and Engineering
James Cook University
Phone:
Email: helene.marsh@jcu.edu.au

If you have any concerns regarding the ethical conduct of the study, please contact: Human Ethics, Research Office, James Cook University, Townsville, Qld, 4811 Phone: (07) 4781 5011 (ethics@jcu.edu.au)

Ivory use and legal understanding survey

Part 1 For each question, please tick ✓ in the box corresponding most closely to your understanding about the laws associated with Ivory.

	Yes	No	Do not know
1. Any of these ivory can be legally traded within Thailand?			
1.1 African ivory (Ivory of elephants naturally live in African continent)			
1.2 Domesticated Asian ivory (Ivory of domesticated elephants legally owned by privates in Thailand)			
1.3 Wild Asian ivory (Ivory from other Asian elephants specified in point 1.2, including those lives in the wild)			
2. Any of the following activities required permission/registration?			
2.1 Trading ivory as a business			
2.2 Wearing ivory jewellery out/in of Thailand			
2.3 Possessing a piece of raw ivory			
2.4 Import or export of ivory out/in of Thailand			
2.5 Trimming tusks from a domesticated elephant			
2.6 Carving/cutting my registered ivory			
2.7 Translocating a registered ivory			

Part 2 For each question, please read the statements in left box, and specify, in the right box, how many of the statement are true for you

Question 1.	
1.1. I have inherited some ivory items. 1.2. *I currently have more than four ivory items being not registered yet.* 1.3. I have got a buying offer for ivory. 1.4. I have owned ivory for more than 10 years. 1.5. I have bought all or most of ivory items myself.	

Question 2.	
2.1 I have recommended others to get ivory item. 2.2 My first ivory item is a jewellery or worn spiritual product. 2.3 All of my ivory is raw (not been carved or manufactured). 2.4 I currently have enough number of ivory items. *2.5 I have bought an ivory from a promotion event in last three years.*	

Question 3.	
3.1 I like characteristics or beautifulness of ivory. 3.2 *I can make money from selling ivory regularly.* 3.3 I am, currently, unaware of ivory price. 3.4 In last 3 years, I have not use ivory as its purposes (only keep or store them). 3.5 I am a member of social media group (e.g. Facebook group) interested in spiritual items.	

Question 4.	
4.1 I am not interested in learning how to distinguish real ivory. 4.2 I have not aware of ivory shop in my living area in last three years. 4.3 I have owned at least one of spiritual ivory items. 4.4 *I have sent/received an ivory across countries in last 3 years.* 4.5 I have seen a foreigner wearing ivory in Thailand.	

(Note: - *Italic and underlined statement indicated sensitive statements that were included only in treatment survey set***)**

Part 3 **Please tick ✔ in the box corresponding to you.**

1. What is your gender?

☐ Male ☐ Female ☐ Other (*specify*) _____

2. What is your age group?

☐ ≤ 20 ☐ 21 – 30 ☐ 31 – 40 ☐ 41 – 50 ☐ 51 - 60 ☐ 61 and over

3. What is your religion?

☐ Buddhism ☐ Islam ☐ Christianity ☐ Hinduism ☐ Other (*specify*) _____

4. What is your education level?

☐ Elementary school not completed ☐ Elementary school completed or equivalent
☐ Junior high school completed or equivalent ☐ High school completed or equivalent
☐ Diploma or equivalent ☐ Bachelor degree ☐ Higher than Bachelor degree
☐ Other (specify) _____

5. What is your occupation?

☐ Government officer ☐ Employee in government organizations
☐ Employee in private organizations ☐ Agriculture ☐ Trades and services
☐ Student ☐ Other (*specify*) _____ ☐ Not working (including retirement)

Please also specify your area of work _____

6. What is the quantity of your ivory items?

☐ least than 5 ☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ 21-25 ☐ 26-30 ☐ more than 30

Thai translation

โครงการวิจัย: การประเมินการปฏิบัติตามกฎหมายของผู้ครอบครองงาช้าง

หัวข้อการสำรวจ: การใช้ประโยชน์งาช้างและความเข้าใจเกี่ยวกับข้อกฎหมาย

ผู้ตอบแบบสำรวจ: ผู้ครอบครองงาช้าง

เอกสารข้อมูลการสำรวจ

ขอเชิญท่านเข้าร่วมการในโครงการวิจัยเกี่ยวกับการค้างาช้างในประเทศไทย ซึ่งดำเนินการวิจัยโดย นางสาวอภิญญา ใจแท้ โดยเป็นส่วนหนึ่งของวิทยานิพนธ์ระดับปริญญาเอกในสาขาเกษตรกรรม สิ่งแวดล้อม และการศึกษาที่เกี่ยวข้อง ณ มหาวิทยาลัยเจมส์คุก ประเทศออสเตรเลีย

หากท่านตอบรับเข้าร่วมการศึกษาในครั้งนี้ ท่านจะตอบแบบสำรวจเกี่ยวกับการใช้ประโยชน์งาช้าง ที่ประกอบไปด้วย 3 ส่วน สองส่วนแรกมีเป้าหมายในการศึกษาข้อมูลทั่วไปของท่านและการใช้ประโยชน์งาช้าง และความเข้าใจทั่วไปเกี่ยวกับข้อกฎหมาย ตามลำดับ โดยส่วนที่ 3 จะเป็นการตอบข้อมูลประชากรศาสตร์เกี่ยวกับตัวท่าน การตอบแบบสำรวจนี้ใช้เวลาประมาณ 10 นาที ทั้งนี้จะไม่มีการเปิดเผยข้อมูลระบุตัวตนของท่านแต่อย่างใด

การเข้าร่วมของท่านเป็นการสมัครใจ โดยท่านสามารถหยุดการดำเนินการได้ตลอดเวลาโดยมิต้องอธิบายหรือเหตุผลแต่อย่างใด การให้สัมภาษณ์นี้จะไม่มีความเสี่ยงที่สามารถคาดคะเนได้ ข้อมูลการตอบแบบสำรวจและรายละเอียดติดต่อของท่านจะไม่มีการระบุตัวตน โดยข้อมูลที่ได้จะใช้ในการตีพิมพ์งานวิจัย การสัมมนา วิทยานิพนธ์ระดับปริญญาเอก เรื่อง ความยั่งยืนของการค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม และรายงานเสนอกรมอุทยานแห่งชาติ สัตว์ป่า และพันธุ์พืช โดยจะไม่มีการระบุตัวตนของท่านในสิ่งพิมพ์เหล่านี้แต่อย่างใด

เมื่อท่านตอบแบบสำรวจแล้วเสร็จ โปรดนำใส่ซองจดหมายที่แนบมานี้ (จ่าหน้าซองและติดแสตมป์เรียบร้อยแล้ว) ปิดผนึก และส่งที่ตู้ไปรษณีย์หรือที่ทำการไปรษณีย์ไทยทุกแห่ง โดยไม่ต้องเขียนชื่อสกุล หรือ ข้อมูลการติดต่อ และไม่ต้องเสียค่าจัดส่งแต่อย่างใด
หากท่านมีข้อสงสัยเกี่ยวกับการดำเนินงานวิจัย โปรดติดต่อ

นักวิจัย:
อภิญญา ใจแท้
คณะวิทยาศาสตร์และวิศวกรรมศาสตร์
มหาวิทยาลัยเจมส์คุก
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อาจารย์ที่ปรึกษา:
เฮเลน มาร์ช
คณะวิทยาศาสตร์และวิศวกรรมศาสตร์
มหาวิทยาลัยเจมส์คุก
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หากท่านมีข้อกังวลเกี่ยวกับข้อกำหนดด้านจริยธรรม โปรดติดต่อ ส่วนจริยธรรมงานวิจัยในมนุษย์ สำนักงานวิจัย มหาวิทยาลัยเจมส์คุก เมืองทาวส์วิว รัฐควีนส์แลนด์ *4811* โทร *(07) 4781 5011 (ethics@jcu.edu.au)*

แบบสำรวจการใช้ประโยชน์งาช้างและความเข้าใจเกี่ยวกับข้อกฎหมายที่เกี่ยวข้อง

ส่วนที่ 1 โปรดอ่านข้อความในคำถามและเลือกทำเครื่องหมาย ✔ ในช่องที่ตรงกับความเข้าใจของท่านในบรรทัดนั้น ๆ

1. งาช้างและผลิตภัณฑ์งาช้างที่สามารถขออนุญาตค้าขายได้ภายในประเทศไทย			
	ค้าขายได้	**ห้ามค้าขาย**	**ไม่ทราบ**
▪ งาช้างแอฟริกา (ช้างที่อาศัยตามธรรมชาติในทวีปแอฟริกา)			
▪ งาช้างบ้านหรือช้างเลี้ยงของไทย (ช้างที่มีเจ้าของ เป็นสัตว์พาหนะ)			
▪ งาช้างป่า (ช้างที่อาศัยในป่าหรือตามธรรมชาติของประเทศไทยและทวีปเอเชีย)			

2. การกระทำที่ต้องแจ้งเจ้าหน้าที่เพื่อจดทะเบียน ปรับปรุงทะเบียน/ข้อมูล หรือขออนุญาตตามกฎหมาย			
	ต้องแจ้ง	**ไม่ต้องแจ้ง**	**ไม่ทราบ**
▪ ทำธุรกิจค้าขายงาช้าง/ผลิตภัณฑ์งาช้าง			
▪ ใส่เครื่องประดับงาช้างเข้ามาในประเทศหรือออกจากประเทศไทย			
▪ มีงาช้าง(ที่ยังไม่แปรรูปหรือแกะสลัก) จำนวน ๑ ชิ้น ในครอบครอง			
▪ นำ/ส่งงาช้างออกไปต่างประเทศ หรือนำงาช้างเข้ามาในประเทศไทย			
▪ ตัดงาของช้างบ้าน (ช้างเลี้ยง)			
▪ นำงาช้างท่อนที่ได้ขึ้นทะเบียนไว้แล้ว ไปแกะสลัก			
▪ ย้ายสถานที่เก็บรักษางาช้าง/ผลิตภัณฑ์งาช้าง			

ส่วนที่ 2 โปรดอ่านข้อความในช่องด้านซ้ายมือ แล้วให้ระบุ**จำนวน**ของข้อความที่ตรงกับท่านในช่องสี่เหลี่ยมด้านขวามือ

ข้อ 1 โปรดอ่านข้อความต่อไปนี้แล้วระบุจำนวนของข้อความที่ตรงกับท่าน	
1.1 ฉันได้รับมรดกเป็นงาช้าง/ผลิตภัณฑ์งาช้าง *1.2 ฉันมีผลิตภัณฑ์งาช้างที่ยังไม่ได้แจ้งครอบครองมากกว่า 4 ชิ้น (เช่น เครื่องประดับงาช้าง เครื่องรางของขลัง งาแกะสลัก ของใช้ต่าง ๆ)* 1.3 มีคนเคยเสนอขอซื้องาช้าง/ผลิตภัณฑ์งาช้างของฉัน 1.4 ฉันครอบครองงาช้าง/ผลิตภัณฑ์งาช้างมาแล้วมากกว่า 10 ปี 1.5 ฉันซื้องาช้าง/ผลิตภัณฑ์งาช้างส่วนใหญ่หรือทั้งหมดด้วยตนเอง	

ข้อ 2 โปรดอ่านข้อความต่อไปนี้แล้วระบุจำนวนของข้อความที่ตรงกับท่าน	
2.1 ฉันเคยแนะนำให้ผู้อื่นซื้อหางาช้าง/ผลิตภัณฑ์งาช้าง 2.2 งาช้างชิ้นแรกของฉันเป็นเครื่องประดับ หรือเครื่องรางวัตถุมงคลที่ใส่หรือพกติดตัวได้ 2.3 งาช้างของฉันทั้งหมดเป็นงาโชว์หรืองาที่มีลักษณะเป็นกิ่งหรือท่อนที่ยังไม่ได้แปรรูป/แกะสลัก 2.4 ในปัจจุบันนี้ ฉันมีงาช้าง/ผลิตภัณฑ์งาช้างในปริมาณที่เพียงพอแล้ว *2.5 ในช่วง 3 ปีที่ผ่านมา ฉันเคยซื้องาช้าง/ผลิตภัณฑ์งาช้างจากงานแสดงสินค้าต่าง ๆ เช่น งานไอทอป*	

ข้อ 3 โปรดอ่านข้อความต่อไปนี้แล้วระบุจำนวนของข้อความที่ตรงกับท่าน	
3.1 ฉันมีความชื่นชอบลักษณะหรือความสวยงามของงาช้าง เช่น สีขาว รูปร่าง ลายงา *3.2 ฉันมีรายได้ส่วนหนึ่งจากการขายงาช้าง/ผลิตภัณฑ์งาช้างอยู่เป็นประจำ* 3.3 ฉันไม่ทราบราคางาช้าง/ผลิตภัณฑ์งาช้างในปัจจุบัน 3.4 ช่วง 3 ปีที่ผ่านมานี้ ฉันไม่ได้ใช้งานงาช้าง/ผลิตภัณฑ์งาช้างของฉัน เช่น ไม่ได้สวมใส่เป็นเครื่องประดับ/วัตถุมงคล ไม่ได้บูชาวัตถุมงคล ไม่ได้วางโชว์หรือประดับตกแต่งบ้าน (เน้นการเก็บรักษาเอาไว้) 3.5 ฉันเป็นสมาชิกของกลุ่มผู้สนใจเกี่ยวกับวัตถุมงคลในอินเตอร์เน็ท เช่น กลุ่มเฟซบุ๊ก	

ข้อ 4 โปรดอ่านข้อความต่อไปนี้แล้วระบุจำนวนของข้อความที่ตรงกับท่าน	
4.1 ฉันไม่มีความสนใจเกี่ยวกับวิธีการสังเกตดูงาช้างแท้ 4.2 ช่วง 3 ปีที่ผ่านมานี้ ฉันไม่เคยเห็นร้านค้างาช้าง/ผลิตภัณฑ์งาช้างในจังหวัดที่ฉันอาศัยอยู่ 4.3 ฉันมีงาช้าง/ผลิตภัณฑ์งาช้างที่เป็นวัตถุมงคลหรือเครื่องรางของขลัง *4.4 ในช่วง 3 ปีที่ผ่านมานี้ ฉันเคยส่งงาช้าง/ผลิตภัณฑ์งาช้างออกไปต่างประเทศ หรือซื้องาช้าง/ผลิตภัณฑ์งาช้างจากต่างประเทศเข้ามา* 4.5 ฉันเคยพบเห็นชาวต่างชาติสวมใส่เครื่องประดับงาช้างในประเทศไทย	

(ข้อความตัวเอียงที่ขีดเส้นใต้ปรากฏเฉพาะแบบสำรวจ ชุดทดสอบ)

ส่วนที่ 3 เลือกทำเครื่องหมาย ✔ ในช่องที่ตรงกับท่าน

1. โปรดระบุเพศของท่าน

☐ เพศชาย ☐ เพศหญิง ☐ อื่นๆ (ระบุ) _____

2. ช่วงเลือกอายุของท่าน

☐ต่ำกว่า 20 ปี ☐21 – 30 ปี ☐31 – 40 ปี ☐41 – 50 ปี ☐51 - 60 ปี ☐61 ปีขึ้นไป

3. ท่านนับถือศาสนาใด

☐ พุทธ ☐ อิสลาม ☐ คริสต์ ☐ ฮินดู ☐ อื่นๆ (ระบุ) _____

4. โปรดระบุระดับการศึกษาของท่าน

☐ ต่ำกว่า ป.6 ☐ ป. 6 หรือเทียบเท่า ☐ ม.3 หรือเทียบเท่า ☐ ม.6 /ปวช.3 หรือเทียบเท่า
☐ อนุปริญญา/ปวส. หรือเทียบเท่า ☐ ปริญญาตรี ☐ สูงกว่าระดับปริญญาตรี ขึ้นไป ☐ อื่นๆ____

5. อาชีพหลักของท่านในปัจจุบันคือข้อใด

☐ ข้าราชการ/พนักงานของรัฐ ☐ พนักงานราชการ/ลูกจ้างหน่วยงานของรัฐ ☐ พนักงานหน่วยงานเอกชน
☐ เกษตรกร ☑ ค้าขาย/การบริการ ☐ นักเรียน/นักศึกษา
☐ อื่นๆ (ระบุ) _____ ☐ ไม่ได้ทำงาน (รวมถึงการเกษียณอายุ)_____

กรุณาระบุสาขางานของท่าน _____

เช่น พยาบาล ครู ฝ่ายรักษาความสะอาด นักวิชาการการศึกษา ค้าขาย เจ้าหน้าที่ฝ่ายปกครอง บัญชี เป็นต้น

6. ปริมาณการครอบครองงาช้าง/ผลิตภัณฑ์งาช้างของท่านคือข้อใด (จำนวนเป็นชิ้น/ท่อน/กิ่ง)

☐ น้อยกว่า 5 ☐ 5-10 ☐ 11-15 ☐ 16 -20 ☐ 21-25 ☐ 26-30 ☐ มากกว่า 30

Table S3.1: *Number of responses and ratios between correct and non-correct ("wrong" and "do not know") answers for Question 1: Do any of this ivory be legally traded within Thailand? categorized by i) Gender, ii) Age class, iii) Education level, iv) Occupation, and v) Ivory possession volume.*

Q1: Tradable status of ivory

Characteristic	African					Wild Asian					Domesticated Asian				
	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio
		Wrong	Do not know	Total			Wrong	Do not know	Total			Wrong	Do not know	Total	
i) Gender															
Female	148	10	85	95	**1.6**	164	10	69	79	**2.1**	72	72	99	171	**0.4**
Male	185	11	58	69	**2.7**	183	19	52	71	**2.6**	99	72	83	155	**0.6**
ii) Age class															
21-40	27	2	7	9	**3.0**	36	2	7	9	**4.0**	15	8	13	21	**0.7**
41-50	46	1	16	17	**2.7**	49	3	11	14	**3.5**	21	20	22	42	**0.5**
51-60	85	3	30	33	**2.6**	92	2	24	26	**3.5**	35	41	42	83	**0.4**
≥ 61 year old	175	15	90	105	**1.7**	179	22	79	101	**1.8**	100	75	105	180	**0.6**
iii) Education level															
< Diploma	41	4	25	29	**1.4**	46	5	19	24	**1.9**	25	15	30	45	**0.6**
Diploma&bachelor	146	8	81	89	**1.6**	150	14	71	85	**1.8**	80	63	92	155	**0.5**
> Bachelor	146	9	37	46	**3.2**	151	10	31	41	**3.7**	66	66	60	126	**0.5**
iv) Occupation															
Business owned	101	2	39	41	**2.5**	103	8	31	39	**2.6**	55	41	46	87	**0.6**
Government employed	23	2	9	11	**2.1**	23	3	8	11	**2.1**	12	8	14	22	**0.5**
Private employee	57	2	17	19	**3.0**	59	2	15	17	**3.5**	23	28	25	53	**0.4**
Do not work	152	15	78	93	**1.6**	162	16	67	83	**2.0**	81	67	97	164	**0.5**
v) Ivory possession volume															
1 - 4	195	4	83	87	**2.2**	204	8	70	78	**2.6**	85	81	116	197	**0.4**
5 - 15	77	4	42	46	**1.7**	81	8	34	42	**1.9**	48	33	42	75	**0.6**
16 - 25	19	0	4	4	**4.8**	21	0	2	2	**10.5**	12	7	4	11	**1.1**
≥26 pcs	27	1	14	15	**1.8**	26	1	15	16	**1.6**	19	3	20	23	**0.8**

Table S3.2: *Number of responses and ratios between correct and non-correct ("wrong" and "do not know") answers for Question 2: Do any of the following activities require an appropriate authorization?, categorized by i) Gender, ii) Age class, iii) Education level, iv) Occupation, and v) Ivory possession volume.*

Q2: Ivory-related restrictions

Characteristic	Triming tusk					Possessing a raw ivory					Translocating ivory					Carving				
	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio
		Wrong	Do not know	Total			Wrong	Do not know	Total			Wrong	Do not know	Total			Wrong	Do not know	Total	
i) Gender																				
Female	134	17	92	109	**1.2**	166	36	41	77	**2.2**	127	46	70	116	**1.1**	130	27	86	113	**1.2**
Male	152	18	84	102	**1.5**	173	38	43	81	**2.1**	143	45	66	111	**1.3**	149	23	82	105	**1.4**
ii) Age class																				
21-40	23	1	12	13	**1.8**	26	6	4	10	**2.6**	26	6	4	10	**2.6**	23	5	8	13	**1.8**
41-50	45	2	16	18	**2.5**	38	12	13	25	**1.5**	27	15	21	36	**0.8**	33	9	21	30	**1.1**
51-60	72	7	39	46	**1.6**	85	12	21	33	**2.6**	70	18	30	48	**1.5**	73	5	40	45	**1.6**
≥ 61 year old	146	25	109	134	**1.1**	190	44	46	90	**2.1**	147	52	81	133	**1.1**	150	31	99	130	**1.2**
iii) Education level																				
< Diploma	32	4	34	38	**0.8**	42	13	15	28	**1.5**	30	10	30	40	**0.8**	32	9	29	38	**0.8**
Diploma&bachelor	131	21	83	104	**1.3**	156	38	41	79	**2.0**	123	51	61	112	**1.1**	129	25	81	106	**1.2**
> Bachelor	123	10	59	69	**1.8**	141	23	28	51	**2.8**	117	30	45	75	**1.6**	118	16	58	74	**1.6**
iv) Occupation																				
Business ow ned	81	4	57	61	**1.3**	94	18	30	48	**2.0**	74	27	41	68	**1.1**	83	14	45	59	**1.4**
Government employed	20	5	9	14	**1.4**	21	11	2	13	**1.6**	20	7	7	14	**1.4**	18	4	12	16	**1.1**
Private employee	55	3	18	21	**2.6**	50	13	13	26	**1.9**	49	10	17	27	**1.8**	44	6	26	32	**1.4**
Do not w ork	130	23	92	115	**1.1**	174	32	39	71	**2.5**	127	47	71	118	**1.1**	134	26	85	111	**1.2**
v) Ivory possession volume																				
1 - 4	161	9	112	121	**1.3**	204	22	56	78	**2.6**	150	40	92	132	**1.1**	148	22	112	134	**1.1**
5 - 15	77	4	42	46	**1.7**	82	19	22	41	**2.0**	72	20	31	51	**1.4**	77	9	37	46	**1.7**
16 - 25	17	2	4	6	**2.8**	15	7	1	8	**1.9**	12	8	3	11	**1.1**	14	4	5	9	**1.6**
≥ 26 pcs	21	3	18	21	**1.0**	24	13	5	18	**1.3**	22	10	10	20	**1.1**	26	2	14	16	**1.6**

Table S3.2: : *Number of responses and ratios between correct and non-correct ("wrong" and "do not know") answers for Question 2: Do any of the following activities require an appropriate authorization?, categorized by i) Gender, ii) Age class, iii) Education level, iv) Occupation, and v) Ivory possession volume. (Cont.)*

Q2: Ivory-related restrictions

Characteristic	Domestic trade					Wearing jewellery across country					Exporting/import ivory				
	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio	Cor-rect	Non-correct			Ratio
		Wrong	Do not know	Total			Wrong	Do not know	Total			Wrong	Do not know	Total	
i) Gender															
Female	198	6	39	45	**4.4**	82	48	113	161	**0.5**	207	7	29	36	**5.8**
Male	220	4	30	34	**6.5**	112	36	106	142	**0.8**	216	6	32	38	**5.7**
ii) Age class															
21-40	30	0	6	6	**5.0**	16	6	14	20	**0.8**	33	0	3	3	**11.0**
41-50	56	0	7	7	**8.0**	25	10	28	38	**0.7**	55	0	8	8	**6.9**
51-60	106	1	11	12	**8.8**	48	20	50	70	**0.7**	101	2	15	17	**5.9**
≥ 61 year old	226	9	45	54	**4.2**	105	48	127	175	**0.6**	234	11	35	46	**5.1**
iii) Education level															
< Diploma	54	3	13	16	**3.4**	23	14	33	47	**0.5**	55	4	11	15	**3.7**
Diploma&bachelor	195	5	35	40	**4.9**	87	39	109	148	**0.6**	195	7	33	40	**4.9**
> Bachelor	169	2	21	23	**7.3**	84	31	77	108	**0.8**	173	2	17	19	**9.1**
iv) Occupation															
Business owned	121	0	21	21	**5.8**	64	16	62	78	**0.8**	122	0	20	20	**6.1**
Government employed	27	3	4	7	**3.9**	9	8	17	25	**0.4**	29	3	2	5	**5.8**
Private employee	66	0	10	10	**6.6**	41	12	23	35	**1.2**	65	1	10	11	**5.9**
Do not work	204	7	34	41	**5.0**	80	48	117	165	**0.5**	207	9	29	38	**5.4**
v) Ivory possession volume															
1 - 4	231	0	51	51	**4.5**	113	35	134	169	**0.7**	239	1	42	43	**5.6**
5 - 15	110	0	13	13	**8.5**	51	18	54	72	**0.7**	110	0	13	13	**8.5**
16 - 25	23	0	0	0	**23/0**	12	4	7	11	**1.1**	20	2	1	3	**6.7**
≥26 pcs	37	0	5	5	**7.4**	10	8	24	32	**0.3**	37	0	5	5	**7.4**

Supplementary information for Chapter 4

Table S4.1: *Specifications of NIR spectrometers used in the study.*

Device	Wavelength (nm)	Resolution (nm)	Measuring mode*	Light source
1	600 – 1100	0.46	Interactance	7 watt halogen
2	700 – 1200	0.23	Interactance	7 watt halogen
3	900 – 1700	2.50	Reflectance	5 watt x 2 LED

** The interactance mode allows the NIR light to penetrate under a surface to interact with the sample and reflect from the sample to the detector mounted in the device. The reflectance mode merely reflects from the surface.*

Table S4.2: *Ivory and spectral sample numbers used in the study.*
LP: Longitudinal plane, XP: Cross-sectional plane
** There is no cross-sectional analysis for within species classification*

Device	**Sources** (Number of tusks)	**Average spectra (N)** (Number of animals)		**Number of scans**		
		LP	**XP***	**LP**	**XP**	**Total**
1	African (29)	29	19	95	21	116
	Wild Asian (30)	17	2	154	3	157
	Domesticated Asian (26)	17	12	103	15	118
	Total (85)	**63**	**33**	**352**	**39**	**391**
2	African (30)	30	29	106	32	138
	Wild Asian (30)	17	2	153	3	156
	Domesticated Asian (26)	17	12	101	15	116
	Total (86)	**64**	**43**	**360**	**50**	**410**
3	African (30)	30	29	101	31	132
	Wild Asian (30)	17	2	155	3	158
	Domesticated Asian (26)	17	12	101	15	116
	Total (86)	**64**	**43**	**357**	**49**	**406**

Table S4.3: *Transformation of NIR data obtained from the three devices.*

Device	Interspecies classification		Within species classification
	Longitudinal	**Cross-sectional**	**Longitudinal**
1	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:169 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:53	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:89 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:63	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:123 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:53 3. SNV
2	1. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:79 2. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:193 3. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:69 4. SNV	1. SNV 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:193 3. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:191 4. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:77	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:197 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:165 3. SNV
3	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:27 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:35	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:31 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:15	1. 2nd Savitzky-Golay Derivative Polynomial Order:2 Smoothing Points:27 2. Savitzky-Golay Smoothing Polynomial Order:2 Smoothing Points:23

Table S4.4: *PLS-DA results from ten repeated samplings in the longitudinal plane for interspecies classification: African and Asian ivory. Results are presented as percentage of correct classification for calibration (Cal), validation (Val) and total datasets, n: represents sample size, PC: number of principal components used for developing each classification model. Number of samples: African ivory = 30 (29 for Device 1), Asian ivory = 34.*

Sampling	Device 1				Device 2				Device 3			
	PC	Cal n=41	Val n=22	Total n=63	PC	Cal n=42	Val n=22	Total n=64	PC	Cal n=42	Val n=22	Total n=64
Sampling 1	8				9				8			
African		94.74%	80.00%	89.66%		100%	100%	100%		100%	80.00%	93.33%
Asian		95.45%	91.67%	94.12%		100%	100%	100%		100%	83.33%	94.12%
Overall		95.12%	86.36%	92.06%		100%	100%	100%		100%	81.82%	93.75%
Sampling 2	12				6				9			
African		100%	100%	100%		95.00%	80.00%	90.00%		100%	90.00%	96.67%
Asian		100%	100%	100%		100%	91.67%	97.06%		100%	83.33%	94.12%
Overall		100%	100%	100%		97.62%	86.36%	93.75%		100%	86.36%	95.31%
Sampling 3	8				12				9			
African		100%	80.00%	93.10%		100%	100%	100%		100%	90.00%	96.67%
Asian		72.73%	33.33%	58.82%		100%	100%	100%		100%	91.67%	97.06%
Overall		85.37%	54.55%	74.60%		100%	100%	100%		100%	90.91%	96.88%
Sampling 4	9				7				6			
African		89.47%	100.0%	93.10%		85.00%	50.00%	73.33%		90.00%	90.00%	90.00%
Asian		100%	91.67%	97.06%		100%	75.00%	91.18%		95.45%	91.67%	94.12%
Overall		95.12%	95.45%	95.24%		92.86%	63.64%	82.81%		92.86%	90.91%	92.19%
Sampling 5	4				12				10			
African		89.47%	70.00%	82.76%		100%	100%	100%		95.00%	60.00%	83.33%
Asian		81.82%	83.33%	82.35%		100%	100%	100%		100%	58.33%	85.29%
Overall		85.37%	77.27%	82.54%		100%	100%	100%		97.62%	59.09%	84.38%
Sampling 6	9				11				11			
African		100%	80.00%	93.10%		100%	70.00%	90.00%		100%	80.00%	93.33%
Asian		100%	83.33%	94.12%		100%	66.67%	88.24%		90.91%	75.00%	85.29%
Overall		100%	81.82%	93.65%		100%	68.18%	89.06%		95.24%	77.27%	89.06%
Sampling 7	9				10				9			
African		100%	70.00%	89.66%		100%	100%	100%		100%	100%	100%
Asian		77.27%	75.00%	76.47%		100%	100%	100%		100%	100%	100%
Overall		87.80%	72.73%	82.54%		100%	100%	100%		100%	100%	100%
Sampling 8	8				4				7			
African		100%	100%	100%		90.00%	90.00%	90.00%		100%	100%	100%
Asian		100%	100%	100%		77.27%	83.33%	79.41%		100%	100%	100%
Overall		100%	100%	100%		83.33%	86.36%	84.38%		100%	100%	100%
Sampling 9	10				12				11			
African		100%	90.00%	96.55%		100%	80.00%	93.33%		100%	100%	100%
Asian		95.45%	100%	97.06%		100%	83.33%	94.12%		100%	100%	100%
Overall		97.56%	95.45%	96.83%		100%	81.82%	93.75%		100%	100%	100%
Sampling 10	8				10				10			
African		100%	90.00%	96.55%		100%	90.00%	96.67%		100%	100%	100%
Asian		100%	91.67%	97.06%		100%	58.33%	85.29%		100%	100%	100%
Overall		100%	90.91%	96.83%		100%	72.73%	90.63%		100%	100%	100%

Table S4.5. *PLS-DA results from ten repeated samplings in the cross-sectional plane for interspecies classification: African and Asian ivory. Results are presented in percentage of correct classification for calibration (Cal), validation (Val) and total datasets, n: represented sample size, PC: number of principal components used for developing each classification model. Number of samples: African ivory = 29 (19 for Device 1), Asian ivory = 14.*

Sampling	Device 1				Device 2				Device 3			
	PC	Cal n=21	Val n=12	Total n=33	PC	Cal n=28	Val n=15	Total n=43	PC	Cal n=28	Val n=15	Total n=43
Sampling 1	4				9				7			
African		100%	100%	100%		100%	100%	100%		100%	100%	100%
Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 2	3				9				8			
African		100%	100%	100%		100%	80.00%	93.10%		100%	100%	100%
Asian		100%	100%	100%		100%	60.00%	85.71%		100%	100%	100%
Overall		100%	100%	100%		100%	73.33%	90.70%		100%	100%	100%
Sampling 3	4				7				6			
African		100%	100%	100%		100%	100%	100%		100%	100%	100%
Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 4	5				6				5			
African		100%	100%	100%		100%	90.00%	96.55%		100%	100%	100%
Asian		100%	100%	100%		88.89%	60.00%	78.57%		100%	100%	100%
Overall		100%	100%	100%		96.43%	80.00%	90.70%		100%	100%	100%
Sampling 5	4				5				8			
African		100%	100%	100%		100%	80.00%	93.10%		100%	100%	100%
Asian		100%	100%	100%		100%	80.00%	92.86%		100%	100%	100%
Overall		100%	100%	100%		100%	80.00%	93.02%		100%	100%	100%
Sampling 6	4				8				6			
African		100%	100%	100%		100%	90.00%	96.55%		100%	100%	100%
Asian		100%	100%	100%		100%	80.00%	92.86%		100%	100%	100%
Overall		100%	100%	100%		100%	86.67%	95.35%		100%	100%	100%
Sampling 7	6				7				6			
African		100%	100%	100%		100%	90.00%	96.55%		100%	100%	100%
Asian		100%	100%	100%		88.89%	80.00%	85.71%		100%	100%	100%
Overall		100%	100%	100%		96.43%	86.67%	93.02%		100%	100%	100%
Sampling 8	9				9				8			
African		100%	100%	100%		89.47%	80.00%	86.21%		100%	100%	100%
Asian		100%	100%	100%		100%	80.00%	92.86%		100%	100%	100%
Overall		100%	100%	100%		92.86%	80.00%	88.37%		100%	100%	100%
Sampling 9	3				9				7			
African		100%	100%	100%		94.74%	70.00%	86.21%		100%	100%	100%
Asian		100%	100%	100%		100%	40.00%	78.57%		100%	100%	100%
Overall		100%	100%	100%		96.43%	60.00%	83.72%		100%	100%	100%
Sampling 10	6				9				5			
African		100%	100%	100%		100%	90.00%	96.55%		100%	100%	100%
Asian		100%	100%	100%		100%	80.00%	92.86%		100%	100%	100%
Overall		100%	100%	100%		100%	86.67%	95.35%		100%	100%	100%

Table S4.6: *PLS-DA results from ten repeated samplings in the longitudinal plane for within species classification: wild and domesticated Asian ivory. Results are presented in percentage of correct classification for calibration (Cal), validation (Val) and total datasets, n: represented sample size, PC: number of principal components used for developing each classification model. Number of samples: wild Asian ivory = 17, domesticated Asian ivory= 17.*

Sampling & ivory source	Device 1				Device 2				Device 3			
	PC	Cal n=22	Val n=12	Total n=34	PC	Cal n=22	Val n=12	Total n=34	PC	Cal n=22	Val n=12	Total n=34
Sampling 1	10				4				3			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 2	8				4				3			
Wild Asian		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Overall		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Sampling 3	9				4				2			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 4	10				7				3			
Wild Asian		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Overall		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Sampling 5	9				5				3			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 6	10				5				3			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 7	10				4				3			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 8	9				5				3			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%
Sampling 9	10				6				3			
Wild Asian		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Overall		100%	83.33%	94.12%		100%	100%	100%		100%	100%	100%
Sampling 10	8				5				3			
Wild Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Dom. Asian		100%	100%	100%		100%	100%	100%		100%	100%	100%
Overall		100%	100%	100%		100%	100%	100%		100%	100%	100%

Info S4.3: *PLS-DA results of the three NIR spectrometers*

1. Interspecies classification

The results of Partial Least Squares Discriminant Analysis (PLS-DA) obtained from 10 repeated samplings separately analyzed in longitudinal and cross-sectional planes for all three devices is presented in **Table R4.1**. Overall interspecies classification results for the longitudinal plane spectra ranged from 74 - 100% of corrected classification rates with Device 3 providing highest median at 96.09% (**Section i**). Device 1 and Device 3 always correctly classified at 100%, the ivory samples from Asian or African elephants for both the calibration and the validation data sets for the cross-sectional analyses (**Section ii**).

Table R4.1: PLS-DA results for interspecies classification: African versus Asian ivory, obtained from the three NIRS devices. *CC, correct classification rates, presented in median and corresponded ranges obtained from the ten repeated samplings. Ivory types: Af: African, As: Asian ivory*.

Device/ ivory type	Calibration			Validation			Total		
	N	CC	CC range	N	CC	CC range	N	CC	CC range
i) Longitudinal plane									
Device 1									
Af	19	100%	89.40-100%	10	85.00%	70.00-100%	29	93.10%	82.76-100%
As	22	97.73%	72.73-100%	12	91.67%	33.33-100%	34	95.59%	58.82-100%
Overall	41	96.34%	85.37-100 %	22	88.64%	54.55-100%	63	94.44%	74.60-100%
Device 2									
Af	20	100%	85.00-100%	10	90.00%	50.00-100%	30	95.00%	73.33-100%
As	22	100%	77.27-100%	12	87.50%	58.33-100%	34	95.59%	79.41-100%
Overall	42	100%	83.33-100%	22	86.36%	63.64-100%	64	93.75%	82.81-100%
Device 3									
Af	20	100%	90.00-100%	10	90.00%	60.00-100%	30	96.67%	83.33-100%
As	22	100%	90.91-00%	12	91.67%	58.33-100%	34	95.59%	85.29-100%
Overall	42	100%	92.86-100%	22	90.91%	59.09-100%	64	96.09%	84.38-100%
ii) Cross-sectional plane									
Device 1									
Af	12	100%	100%	7	100%	100%	19	100%	100%
As	9	100%	100%	5	100%	100%	14	100%	100%
Overall	21	100%	100%	12	100%	100%	33	100%	100%
Device 2									
Af	19	100%	89.47-100%	10	90.00%	70.00-100%	29	90.00%	86.21-100%
As	9	100%	88.89-100%	5	80.00%	40.00-100%	14	80.00%	78.57-100%
Overall	28	100%	92.86%-100%	15	83.33%	60.00-100%	43	93.02%	83.72-100%
Device 3									
Af	19	100%	100%	10	100%	100%	29	100%	100%
As	9	100%	100%	5	100%	100%	14	100%	100%
Overall	28	100%	100%	15	100%	100%	43	100%	100%

1.1 Longitudinal plane

Interspecies classification results from the longitudinal plan spectra show overall medians ranging from 93.75% (Device 2) to 96.09% (Device 3) of corrected classification rates (**Table R4.1, section i)**. As the results of all replicates were similar (**Table S4.4**), Principal Component Analysis (PCA), based on the PLS algorithm, was illustrated for the first sampling data to represent the information related to the important variables for classification (**Figure R4.1**).

PCA score plots of all three devices showed overlapping of data samples (**Figure R4.1, A**). The ivory spectra (**Figure R4.1, B)** are presented to compare with regression coefficient plots of each PLS-DA model developed from each device (**Figure R4.1, C**). The labelled peaks in the plot show the major variables needed to predict the ivory types. Peaks around 960, 1060-1070, and 1150 nm were important in differentiating ivory types for at least two devices (labelled with symbols). NIR light absorption obtained from Device 1 was noticeably different between ivory types at wavelengths around 680 - 850 nm (**Figure R4.1, B-i**), which the corresponding classification model was largely contributed by the absorbance in the region (**C-i**). Variables around 1170 nm were important in differentiating ivory using Device 2 (**Figure R4.1, C-ii)**, while the absorbance in the region of 1215, 1385, 1430 and 1585 nm were responsible for differentiating the ivory types using Device 3 (**Figure R4.1, C-iii**).

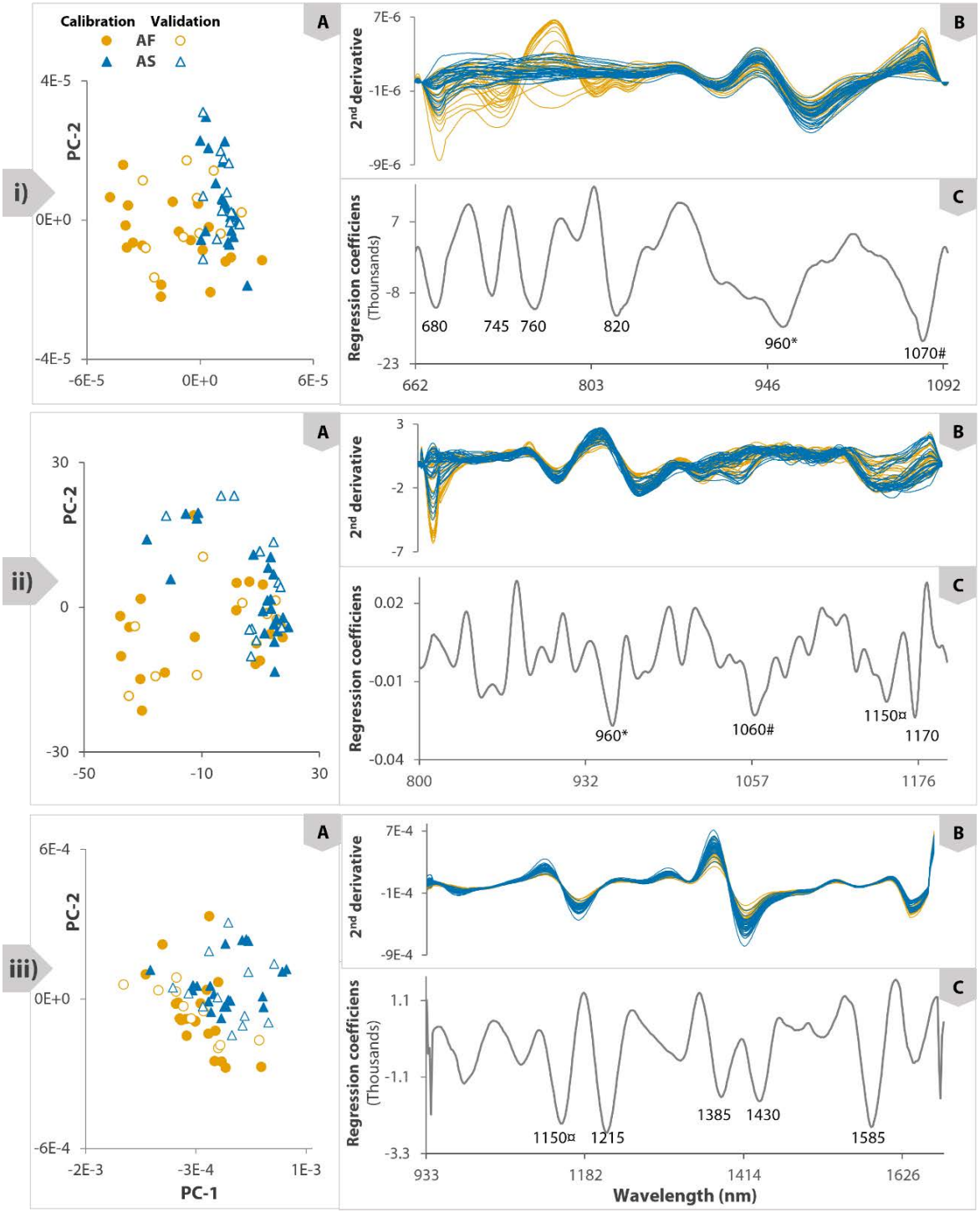

Figure R4.1: *PCA score plots for PC-1 and PC-2 for classifying between African and Asian ivory in longitudinal plane (**A**), processed spectra (**B**) and regression coefficients (**C**) corresponded to the interspecies classification of dentine and cementum for Device 1 (**i**) and Device 2 (**ii**), and cementum only for Device 3 (**iii**). Orange markers/lines: African ivory, blue markers/lines: Asian ivory. There was no clear separation of data between the two ivory species in the PCA score plots obtained from three devices (A). Device 1 depicted spectra difference of spectra pattern around region 680-850 nm (B-i), while Device 3 showed variation of light absorbance intensity (B-iii). The coincident variables* for interspecies classification in *longitudinal plane included regions at 960, 1060-1070, and 1150 nm (C, identical symbols indicated the same regions).*

1.2 Cross-sectional plane

For cross-sectional spectra, Device 1 and Device 3 were both 100% correct for both the calibration and the validation sets for all 10 samplings, while Device 2 had a median of overall correct classification rates of 93% (**Table R4.1, section ii)**. Individual results for each sampling are presented in **Table S4.5**, PCA score plots and regression coefficients from my first sampling was illustrated here (**Figure R4.2**).

The classification results correspond with the grouping of samples illustrated in the PCA score plots (**Figure R4.2, A**); ivory types were best discriminated by Device 1 and Device 3 (**A-i** and **A-iii**). Spectral differences between the ivory from the two different species of elephant were noticeable for all devices. Device 1's processed spectra showed divergent absorption around the 650-830 nm region (**Figure R4.2, B-i**), whereas Device 2 and Device 3 differed in absorption intensities along scanning wavelengths (**B-ii** and **B-iii)**.

Negative peaks at 950-960 nm contributed to the development of all three classification models, while regions around 800-815 and 990-995 nm were important for discriminating the ivory species for at least two devices (**Figure R4.2, C).** Device 1's classification model was also influenced by regions at 685, 740 and 770 nm (**Figure R4.2, C-i**). Important peaks for discriminating between African and Asian ivory also included 1075 and 1160 nm using Device 2 (**Figure R4.2, C-ii**), as well as 1550 nm for Device 3 (**C-iii**).

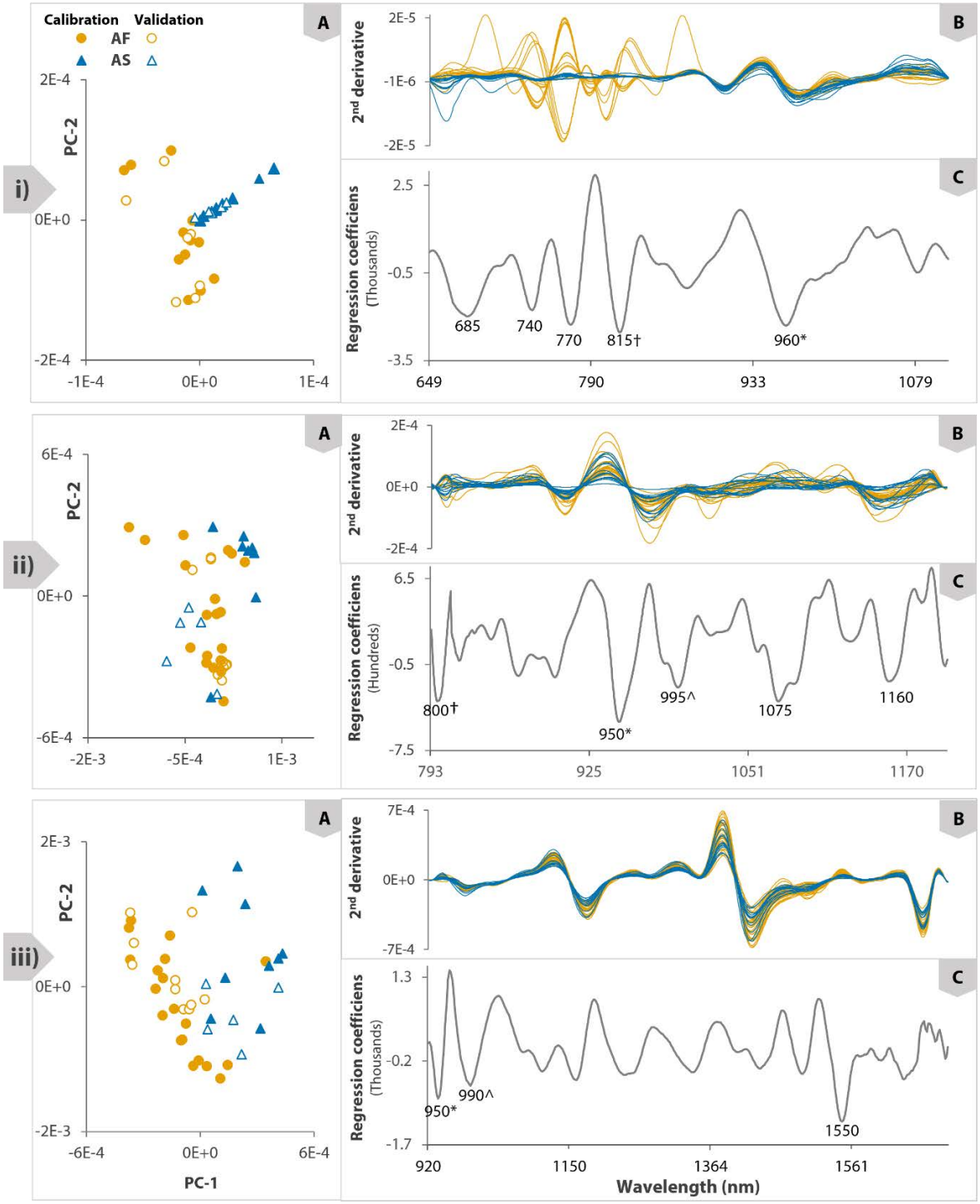

Figure R4.2: *PCA score plots for PC-1 and PC-2 for classifying between dentine tissue African and Asian ivory (cross-sectional plane) (**A**), processed spectra (**B**) and regression coefficients (**C**) derived from Device 1 (**i**), Device 2 (**ii**) and Device 3 (**iii**). Orange markers/lines: African ivory, blue markers/lines: Asian ivory. Dentine data are different between two ivory species as evidenced by the data clustered within ivory type in the PCA score plots (A) and distinct light absorption (B) of all three devices, particularly more obvious for Device 1 (i) and Device 3 (iii). Classifications are coincidently influenced by absorbance around 800 – 815 nm, 950 – 960 nm and 990 – 995 nm (C; identical symbols indicated the same regions).*

2. Within species classification

In distinguishing between domestic and wild Asian elephant ivory, all three devices yielded 100% of the median of correct classification rates. Device 2 and Device 3 were 100% correct for both the calibration and the validation sets, while Device 1 ranged from 94.12% to 100% (**Table R4.2**). The results of ten repeated samplings were presented in **Table S4.6**. The PCA score plot and regression coefficients illustrated here were from the first sampling (**Figure R4.3**).

Table R4.2: PLS-DA results for within species classification: wild versus domesticated Asian ivory, in the longitudinal plane, obtained from the three NIRS devices. *CC, correct classification rates, presented in median and corresponded ranges obtained from the ten repeated samplings. Ivory types: WAs: wild Asian, DAs: domesticated Asian ivory.*

Device/ ivory type	Calibration			Validation			Total		
	N	CC	CC range	N	CC	CC range	N	CC	CC range
Device 1									
WAs	11	100%	100%	6	100%	83.33-100%	17	100%	94.12-100%
DAs	11	100%	100%	6	100%	83.33-100%	17	100%	94.12-100%
Overall	22	100%	100%	12	100%	83.33-100%	34	100%	94.12-100%
Device 2									
WAs	11	100%	100%	6	100%	100%	17	100%	100%
DAs	11	100%	100%	6	100%	100%	17	100%	100%
Overall	22	100%	100%	12	100%	100%	34	100%	100%
Device 3									
WAs	11	100%	100%	6	100%	100%	17	100%	100%
DAs	11	100%	100%	6	100%	100%	17	100%	100%
Overall	22	100%	100%	12	100%	100%	34	100%	100%

Ivory sample types are clearly differentiated for the PCA score plot obtained from Device 3 (**Figure R4.3, A-iii**), while the score plots obtained from Device 1 and Device 2 showed subtle separation of the spectral data (**A-i** and **A-ii**). The spectra from the ivory from wild and domesticated Asian elephants were generally similar in their patterns of light absorption with the appearance of peaks in the same region for all three devices, but with differences in absorbance intensities (**Figure R4.3, B**). The separation between the spectra of the two Asian elephant ivory types was apparent in the spectra from Device 3 where the spectra of each ivory types were close together and formed separate layers (**Figure R4.3, B-iii**).

The differentiation between wild and domesticated sources of Asian ivory of the major variables used in the classification models for Device 1 and Device 2, coincidently corresponded with regions around the 930 - 1090 nm (**Figure R4.3, C-i** and **C-ii**). The variable region at 960 nm was also important for discriminating the sources of ivory using Device 3 (**Figure R4.3, C-iii)**. In addition, peaks at 700 and 800 nm also corresponded to classification model of Device 1 (**Figure R4.3, C-i)**. The classification based on the data from Device 3 was also influenced by absorption regions at 1405 and 1550 nm (**Figure R4.3, C-iii)**.

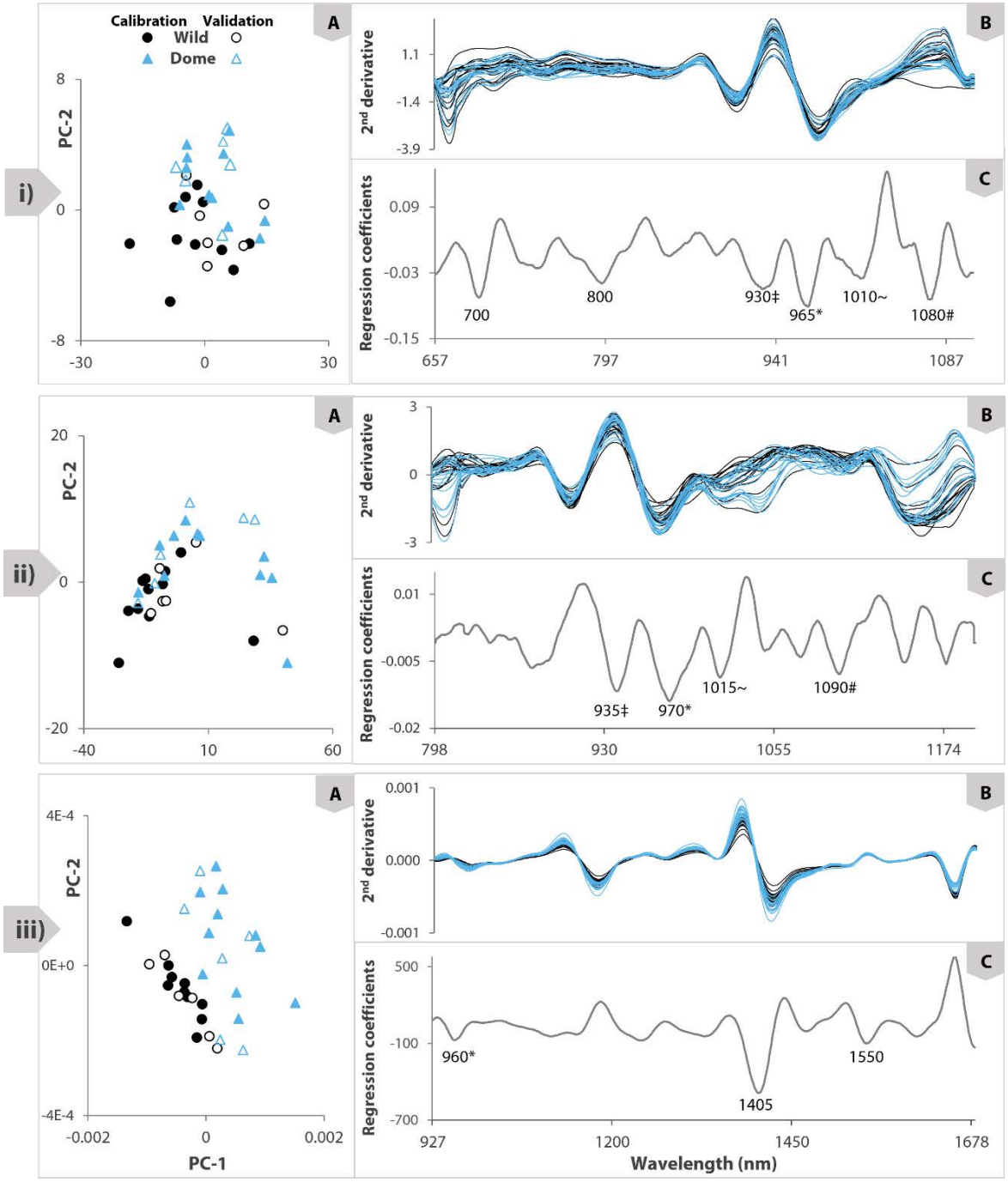

Figure R4.3: *PCA score plots for PC-1 and PC-2 for differentiating between wild and domesticated sources of Asian ivory in longitudinal plane (**A**), processed spectra (**B**) and regression coefficients (**C**) derived from Device 1 (**i**), Device 2 (**ii**) and Device 3 (**iii**). Black markers/lines: wild Asian ivory, blue markers/lines: domesticated Asian ivory. The PCA score plot from Device 3 shows noticeable differentiation of the dentine data between the two Asian ivory types (A-iii), while dentine and cementum sampled by the two interactant devices show data similarity by PC-1 and PC-2 (A-i and A-ii). However, separated layers of light absorbance are also visible between two ivory spectra presented in Device 2 (B-ii), besides Device 3 spectra (B-iii). The absorption regions at 930-935 nm, 960-970 nm, 1010-1015 nm and 1080-1090 nm importantly contributes to the classifications in at least two devices (C; identical symbols indicate the same regions).*

Supplementary information for Chapter 6

Info S6.1: *Survey used for collecting data on ivory use and consumption*

PROJECT TITLE: The elephant ivory trade in Thailand: Demand, supply and control

Survey name: Ivory use

Participant: Potential ivory buyers

SURVEY INFORMATION SHEET

You are invited to take part in a project that is studying the elephant ivory trade in Thailand. The study is being conducted by Apinya Chaitae as part of her Doctor of Philosophy degree in Agriculture, Environmental and Related Studies at James Cook University, Australia.

If you agree to be involved in the study, you will be asked to complete a two-part survey. The first part aims to explore your use of ivory, your beliefs about ivory the reasons you buy. The second part aims to help us understand your background. The survey should take about 10 minutes of your time. We will not disclose your identity.

Taking part in this study is voluntary and you can end your participation at any time without explanation or prejudice. There are no foreseeable risks to you by participating in this research project. Your responses and contact details will be strictly confidential. The data from the study will be used in research publications and Apinya's doctoral thesis (dissertation) entitled "Sustainability of the elephant ivory trade in Thailand: Demand, supply and control" and reports to Thai government. You will not be identified in any way in these publications.

If you have any questions about the study, please contact -

Principal Investigator:
Apinya Chaitae
College of Science and Engineering
James Cook University
Phone:
Email: Apinya.chaitae@my.jcu.edu.au

Supervisor:
Helene Marsh
College of Science and Engineering
James Cook University
Phone:
Email: helene.marsh@jcu.edu.au

If you have any concerns regarding the ethical conduct of the study, please contact: Human Ethics, Research Office, James Cook University, Townsville, Qld, 4811 Phone: (07) 4781 5011 (ethics@jcu.edu.au)

Ivory use survey

Part 1 Ivory use

1. How did you find out about this shop?

☐ Recommended by another person ☐ Known to me ☐ Near where I live ☐ Internet
☐ leaflet ☐ Passing by ☐ Promotion event ☐ Other (*specify*) _____

2. What is the reason for your visiting this shop today?

☐ Buy ivory for myself ☐ Buy ivory for others ☐ Have a look
☐ Sell/swap ivory ☐ Repair ivory items ☐ Other (*specify*) _____

3. What is the estimated distance between this shop and your living place?

☐ Under 50km ☐ 51-100km ☐ 101-200km ☐ 201-300km ☐ 301-400km ☐ Over 400 km

4. What sorts of ivory products are you interested in buying (tick as many as you like)? If none, please skip

☐ Necklace ☐ Brace lace ☐ Bangle ☐ Ring ☐ Earing ☐ Pendant
☐ Belt buckle ☐ Knife/sword ☐ Sacred items ☐ Bead/parts ☐ Raw ivory
☐ Other (*specify*)_____

5. How many ivory items do you own? (including today's purchase, if any)

☐ 0 ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ 7-10 ☐ over 10

6. How did you get your first ivory items?

☐ Bought myself ☐ Inherited ☐ Been given ☐ Other (*specify*) _____

7. Do any of your family and friends have ivory? ☐ I Don't know

☐ Immediate family members/Relatives ☐ Friends/Colleagues ☐ Other (*specify*) _____

8. How any of these factors influent your decision in buying ivory?

	Strongly agree	**Agree**	**Neutral**	**disagree**	**Strongly disagree**
Belief/value					
Ivory quality/Beautifulness					
Beautifulness/skilfulness of combined materials					
Ability to authenticate ivory					
The ivory comes from elephants are well looked after					
Type of ivory (e.g. Asian wild, Asian domestic and African ivory)					
Price					
Credibility of the shop					
Trade permission of the shop					
Shop with physical address					
Products comes with the sale certificate					
Others (specify)					

9. Please share your experience/beliefs regarding ivory

_____
_____
_____

10. Do any of these characteristics of ivory cause you to buy it?

	Strongly agree	Agree	Neutral	disagree	Strongly disagree
Pure					
Beautiful					
Bring good luck					
Protection from bad luck					
Makes me feel confident					
Makes me feel respected/ powerful					
Luxury					
Investment					
Collectible					
Others (specify)					

11. Do you believe in the power of any other good luck charms?

☐ Yes ☐ No If Yes, please tell me more _____

_____

_____

Part 2 Demographics and background (Tick one for each question)

12. What is your gender?

☐ Male ☐ Female ☐ Other (*specify*) _____

13. What is your age group?

☐ ≤20 ☐ 21 – 30 ☐ 31 – 40 ☐ 41 – 50 ☐ 51 - 60 ☐ 61 and over

14. What is your religious?

☐ Buddhism ☐ Islam ☐ Christianity ☐ Hinduism ☐ Other (*specify*) _____

15. What is your education level?

☐ Primary education not completed ☐ Primary education completed or equivalent
☐ Secondary education completed or equivalent ☐ Diploma or equivalent
☐ University level ☐ Other (*specify*) _____

16. What is your occupation?

☐ Government employed ☐ Private employee ☐ Student
☐Business owned (e.g Agriculture, trades, services ☐ Other (*specify*) _____
☐ Not working
Please also specify your area of work _____

17. What is your monthly income (Baht)?

☐ 15,000 and under ☐ 15,001 – 30,000 ☐ 30,001 – 45,000
☐ 45,001 – 60,000 ☐ 60,001 dand over

Thai translation

โครงการวิจัย: การค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม

หัวข้อการสำรวจ: การใช้ประโยชน์งาช้าง

ผู้ตอบแบบสำรวจ: ผู้ซื้องาช้าง

เอกสารข้อมูลการสำรวจ

ขอเชิญท่านเข้าร่วมการในโครงการวิจัยเกี่ยวกับการค้างาช้างในประเทศไทย ซึ่งดำเนินการวิจัยโดย นางสาวอภิญญา ใจแท้ โดยเป็นส่วนหนึ่งของวิทยานิพนธ์ระดับปริญญาเอกในสาขาเกษตรกรรม สิ่งแวดล้อม และการศึกษาที่เกี่ยวข้อง ณ มหาวิทยาลัยเจมส์ดุก ประเทศออสเตรเลีย

หากท่านตอบรับเข้าร่วมการศึกษาในครั้งนี้ ท่านจะตอบแบบสำรวจเกี่ยวกับการใช้ประโยชน์งาช้าง ที่ประกอบไปด้วย 2 ส่วน ส่วนแรกมีเป้าหมายในการศึกษารูปแบบการใช้ประโยชน์ ความเชื่อเกี่ยวกับงาช้าง และเหตุผลในการซื้องาช้าง โดยส่วนที่ 2 จะเป็นการตอบข้อมูลทั่วไปเกี่ยวกับตัวท่าน การตอบแบบสำรวจนี้ใช้เวลาประมาณ 10 นาที ทั้งนี้จะไม่มีการเปิดเผยข้อมูลระบุตัวตนของท่านแต่อย่างใด

การเข้าร่วมของท่านเป็นการสมัครใจ โดยท่านสามารถหยุดการดำเนินการได้ตลอดเวลาโดยมิต้องอธิบายหรือเหตุผลแต่อย่างใด การให้สัมภาษณ์นี้จะไม่มีความเสี่ยงที่สามารถคาดคะเนได้ การให้สัมภาษณ์และรายละเอียดติดต่อของท่านจะเป็นความลับ โดยข้อมูลที่ได้จะใช้ในการตีพิมพ์งานวิจัยและวิทยานิพนธ์ระดับปริญญาเอก เรื่อง ความยั่งยืนของการค้างาช้างในประเทศไทย: อุปสงค์ อุปทาน และการควบคุม และรายงานเสนอกรมอุทยานแห่งชาติ สัตว์ป่า และพันธุ์พืช โดยจะไม่มีการระบุตัวตนของท่านในสิ่งพิมพ์เหล่านี้แต่อย่างใด

หากท่านมีข้อสงสัยเกี่ยวกับการดำเนินงานวิจัย โปรดติดต่อ

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คณะวิทยาศาสตร์และวิศวกรรมศาสตร์
มหาวิทยาลัยเจมส์ดุก
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หากท่านมีข้อกังวลเกี่ยวกับข้อกำหนดด้านจริยธรรม โปรดติดต่อ ส่วนจริยธรรมงานวิจัยในมนุษย์ สำนักงานวิจัย มหาวิทยาลัยเจมส์ดุก เมืองทาวส์วิว รัฐควีนส์แลนด์ *4811* โทร *(07) 4781 5011 (ethics@jcu.edu.au)*

แบบสำรวจเกี่ยวกับการใช้ประโยชน์งาช้าง

ส่วนที่ 1 การใช้ประโยชน์งาช้าง

1. ท่านรู้จักร้านนี้ได้อย่างไร

☐ มีคนแนะนำ ☐ รู้จักกัน ☐ ใกล้เคียงที่พัก ☐ ทราบจากอินเทอร์เน็ต
☐ ใบปลิว ☐ อยู่บนเส้นทางผ่าน ☐ บูธแสดงสินค้า ☐ อื่นๆ (ระบุ) _____

2. ท่านมาร้านในวันนี้ด้วยเหตุผลใด?

☐ ซื้องาช้างให้ตัวเอง ☐ ซื้องาช้างให้ผู้อื่น ☐ ดูสินค้า ☐ ขาย/แลกเปลี่ยน ☐ ซ่อมแซมงาช้าง ☐ อื่นๆ (ระบุ) __

3. ระยะทางโดยประมาณจากบ้านของท่านถึงร้านค้าคือข้อใด

☐ 50 กม. หรือน้อยกว่า ☐ 51-100 กม. ☐ 101-200 กม. ☐ 201-300 กม. ☐ 301-400 กม. ☐ มากกว่า 400 กม. ขึ้นไป

4. สินค้างาช้างชนิด/ประเภทใดที่ท่านให้ความสนใจซื้อ/จะซื้อ (เลือกได้มากกว่า 1 ข้อ)

☐ สร้อยคอ ☐ สร้อยข้อมือ ☐ กำไล ☐ แหวน ☐ ต่างหู ☐ จี้ ☐ หัวเข็มขัด
☐ ด้าม/ส่วนประกอบเป็นงาช้าง ☐ เหรียญ/พระเครื่อง/วัตถุมงคล ☐ เม็ด/อะไหล่ ☐ งาดิบ ☐ อื่นๆ (ระบุ) _____

5. ท่านมีงาช้างอยู่จำนวนกี่ชิ้น (รวมที่ซื้อในวันนี้ด้วย ถ้ามี)

☐ 0 ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ 7-8 ☐ 9-10 ☐ มากกว่า 10

6. ท่านได้งาช้างชิ้นแรกมาอย่างไร

☐ ซื้อ ☐ ได้รับมรดก ☐ มีคนให้มา ☐ อื่นๆ (ระบุ) _____

7. คนที่ท่านรู้จักกลุ่มใดมีหรือใช้งาช้าง ☐ ไม่ทราบ

☐ สมาชิกครอบครัว/ญาติ ☐ เพื่อน/เพื่อนร่วมงาน ☐ อื่นๆ (ระบุ) _____

8. ปัจจัยเหล่านี้มีผลต่อการตัดสินใจซื้องาช้างในระดับใด

ปัจจัย	มีผลมากที่สุด	มีผล	ไม่แน่ใจ	ไม่มีผล	ไม่มีผลมากที่สุด
พุทธคุณ/ฤทธิ์อำนาจของงาช้าง					
ลักษณะและความสวยงามของงาช้าง					
ความสวยงาม/ปราณีตในการแกะสลักและวัสดุประกอบ					
ความสามารถของท่านในการดูงาช้างแท้					
งาช้างได้มาจากช้างที่ได้รับการดูแลอย่างดี					
ประเภทงาช้าง (เช่น งาช้างป่า งาช้างบ้าน งาช้างแอฟริกา)					
ราคา					
ความน่าเชื่อถือของร้านค้า					
ร้านค้าได้รับอนุญาตค้าขายอย่างถูกต้อง					
ร้านค้ามีหน้าร้านและที่ตั้งที่ชัดเจน					
มีหนังสือกำกับการค้างาช้างพร้อมสินค้า					
อื่นๆ ระบุ.....					

9. กรุณาเล่าถึงประสบการณ์หรือความเชื่อของท่านเกี่ยวกับงาช้าง

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10. คุณสมบัติของงาช้างเหล่านี้ตรงกับการใช้งาช้างของคุณในระดับใด

คุณสมบัติของงาช้าง	จริงมากที่สุด	จริง	ไม่แน่ใจ	ไม่จริง	ไม่จริงมากที่สุด
มีสีขาวที่สื่อถึงความบริสุทธิ์					
มีความสวยงาม					
นำโชคดี/นำโชคมาให้/เป็นสิริมงคล					
ป้องกันบัดเป่าสิ่งชั่วร้าย/แคล้วคลาด					
ทำให้มีความเชื่อมั่น					
ทำให้เป็นที่เคารพนับถือ/เกรงขาม					
ดูหรูหรา มีฐานะ					
เป็นการลงทุน					
เป็นของสะสม/ของเก่า					
อื่นๆ (ระบุ)					

11. ท่านมีความเชื่อในวัตถุมงคลอื่นใดหรือไม่

☐ ไม่มี ☐ มี โปรดระบุรายละเอียด _____

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ส่วนที่ 2 ข้อมูลด้านประชากร (เลือกเพียงหนึ่งตัวเลือกในแต่ละคำถาม)

12. โปรดระบุเพศของท่าน

☐ ชาย ☐ หญิง ☐ อื่นๆ (ระบุ) _____

13. โปรดเลือกช่วงอายุของท่าน

☐ 20 ปี หรือต่ำกว่า ☐ 21 – 30 ปี ☐ 31 – 40 ปี ☐ 41 – 50 ปี ☐ 51 - 60 ปี ☐ 61 ปีขึ้นไป

14. ท่านนับถือศาสนาใด

☐ พุทธ ☐ อิสลาม ☐ คริสต์ ☐ ฮินดู ☐ อื่นๆ (ระบุ) _____

15. โปรดระบุระดับการศึกษาของท่าน

☐ ต่ำกว่า ป.6 ☐ ป. 6 หรือเทียบเท่า ☐ ม.3 หรือเทียบเท่า ☐ ม.6 /ปวช.3 หรือเทียบเท่า

☐ อนุปริญญา/ปวส. หรือเทียบเท่า ☐ ตั้งแต่ระดับปริญญาตรี ขึ้นไป ☐ อื่นๆ (ระบุ) _____

16. อาชีพหลักของท่านคือข้อใด (หากท่านไม่ได้ทำงาน โปรดข้าม)

☐ ข้าราชการ/ลูกจ้างภาครัฐ ☐ ลูกจ้าง/พนักงานหน่วยงานเอกชน ☐ นักเรียน/นักศึกษา

☐ เจ้าของกิจการ (เกษตรกร/ธุรกิจ/ค้าขาย/การบริการ ☐ อื่นๆ (ระบุ) _____

โปรดระบุสาขางานของท่าน _____

17. รายได้ต่อเดือนของท่านอยู่ในช่วงใด (บาท)

☐ 15,000 หรือต่ำกว่า ☐ 15,001 – 30,000 ☐ 30,001 – 45,000 ☐ 45,001 – 60,000 ☐ 60,001 ขึ้นไป