Exploring socio-technological-ecological dimensions of Asian songbird trade

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Intellectual Property and Publication Statements

I confirm that the work submitted is my own, except where work which has formed part of jointly authored publications has been included. My contribution and the other authors to this work has been explicitly indicated below. I confirm that appropriate credit has been given within the thesis where reference has been made to the work of others.

Chapters 1 and 7 (the Introduction and Discussion chapters) are solely written by me; **Chapters 2 through 6** are based on work from jointly authored publications. The details of which are as follows.

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Abstract

Since its inception, conservation has grappled with the 'problem' of wildlife trade, often overlooking the experience of animals, plants, and humans involved in the trade chain. By integrating political ecology, machine learning, and design theory, this thesis redefines wildlife trade as a multifaceted issue, or a 'wicked problem'. The thesis focuses on the trade of live songbirds as pets in Indonesia, a trade deeply embedded in culture, monetized, diverse, and often illegal. Given increasing trade, the International Union for the Conservation of Nature termed the phenomenon of over-harvesting birds as the Asian Songbird Crisis (ASC). I examine the premise that species identification is a significant barrier to combating the illegal songbird trade in Indonesia and explore the development of taxonomic aids for conservation law enforcement. I show that image-based machine learning shows promise for identifying birds in complex trade environments (Chapter 2). However, focusing on a single solution, like a taxonomic aid, may solve some issues (species identification) while exacerbating others (enforcement challenges). Enforcement mostly focuses on community-based policing and education for vendors (socialisasi) (Chapter 3). In Chapter 4, I explore user-centered design of taxonomic aids with conservation law enforcement (CLE). Barriers to technology adoption include the social acceptability of bird trade, corruption, and the need for verbal evidence in court. There are diverse attitudes towards the ASC, with many CLE actors not recognizing the crisis label. Market mechanisms shift harvesting pressure onto similar species, suggesting a sustainability-focused narrative may be more productive (Chapter 5). Chapter 6 develops a more-than-human political ecology approach, exploring the interconnectedness between people and birds in trade. This chapter highlights previously obscured harms to birds, such as feather plucking, dismemberment, and overcrowding. Future research should explore alternatives to punitive measures to address unsustainable wildlife trade embedded within complex cultural practices.

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List of Abbreviations

AI: Artificial intelligence

ASC: Asian Songbird Crisis

ASTSG: Asian Songbird Trade Specialist Group

CITES: Convention for the International Trade in Endangered Species

CLE: Conservation law enforcement

CLEO: Conservation law enforcement officer

IUCN: International Union for the Conservation

IUCN SSC: International Union for the Conservation Species Survival Commission

Chapter 1. Introduction

1.1. Wildlife trade as a phenomenon

The world is in the midst of a mass extinction event caused by capitalist processes such as climate change, habitat loss, and over-exploitation (Scheffers et al. 2019). The legal and illegal trade in wildlife (IWT) is often listed as a driver of species overexploitation, involving thousands of animal, plant, and fungi species and billions of individuals (Phelps et al. 2016). Over 34,000 plant species are listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an international trade agreement, designed to prevent the over-exploitation of animals and plants (Hinsley et al. 2016). Approximately 6,600 animal species are on CITES, dominated by reptiles and fish (CITES Secretariat 2022). The exact number of fungi species traded globally is not well-documented, though it is known that close to 1,000 edible mycorrhizal fungi (EMF) are consumed and may be traded (Pérez-Moreno et al. 2021)

Extractive illicit economies that harm the environment are also known as environmental crimes, such as illegal trafficking in flora and fauna (Brombacher et al. 2021). IWT can be defined as the collection of endangered species, protected wildlife and their derivative products for purchasing, selling, or exchanging (Wyatt 2009). The ‘illegal’ aspect generally refers to economic activities that are classified as illegal by national or international legislation (Brombacher et al. 2021).

Importantly, wildlife trade is by no means consistently categorized as a problem and most wildlife trade is legal (Marshall et al. 2025). In discussions about wildlife trade within conservation, some argue that wildlife trade can be legal, sustainable and traceable. Hughes et al. (2023) argue that at ‘its best, wildlife trade can protect biodiversity, maintain ecosystem function, and support local livelihoods’. There are multiple cases of sustainable offtake, most notably in the harvesting of several crocodile species for leather (Roe et al. 2020). Others have labelled well-managed wildlife trade a ‘mirage’ (D’Cruze et al. 2020), arguing against wildlife consumption based on its public health risks like zoonosis (e.g. H1N1, COVID-19) (Yang et al. 2020), or from the welfare implications in the live animal trade (Wyatt et al. 2022).

1.1.1. Treating wildlife trade as more than just a conservation problem

IWT is a highly heterogeneous term. It encompasses a diversity of taxa, scales (very local to very global trade), value-per-unit (e.g. a small cost per kilo for illegal fish, a huge cost per a kilo for other products, e.g. rhino horn), and degrees of legality (clearly illegal, 'grey' trade, illegal-but-tolerated). Often framed through a conservation lens (largely due to the risk of species decline), both legal and illegal wildlife trades are seen as issues of welfare (Wyatt et al. 2022) and public health (Yang et al. 2020), but also as causing cultural (Liew et al. 2021) and economic (Lunstrum et al. 2023) inequalities, poor labour standards (Simlai and Sandbrook 2024) and contraventions of human rights (Osorio and Bernaz 2024). Duffy (2022, p.34) argues that IWT needs to be tackled as a matter of conservation, inequality and development, an approach which generally suggests a greater focus on incentives for local people to engage in conservation rather than IWT (Cooney and Challender 2020).

Through this thesis, IWT is conceptualised not just as a technical or legalistic occurrence but with an appreciation for the political (and cultural) economy in which IWT takes place. IWT is often framed as a crime since certain activities make it unlawful (Duffy 2022, p.31), yet it is wrapped up in preexisting economic and social practices. In many countries, before wildlife trade could even be considered within a legal-illegal binary, wildlife was commodified, sold and exchanged in dynamic 'circuits', with animal capital (Hodgetts and Lorimer 2015) derived from their status as living beings (Collard and Dempsey 2013). These circuits are economies where wildlife is commodified through harvest and exchange, re-commodified through resale or auctions or unmade as commodities through reintroduction or death (Collard and Dempsey 2013).

These structures and human-wildlife relationships exist independently of wildlife trade laws. IWT, like other issues in conservation, is a "wicked problem", where complex social, political, and economic factors interact to produce multiple conflicting goals (Thomas-Walters et al. 2020). A change of law, not a change of practice, often creates an 'illegal' wildlife trade, and the complex, pre-regulatory social and economic structures are central to what makes IWT a wicked problem and too complex to characterize into the reductive binary of legal and illegal. Take the case of the totoaba fish (*Totoaba macdonaldi*) trade; hunters have been participating in an economy that long pre-dates the decline or interest in the vaquita (*Phocoena sinus*), a small and critically endangered porpoise endemic to the Gulf of Mexico that eats totoaba. More recently, drug cartels have pursued profits from selling totoaba bladders to luxury markets in East Asia (Shailer 2024). Only then did this affect local vaquita populations. Now, hunters are portrayed as 'nuisances or gun-toting vigilantes by conservation strategies' (Shailer 2024). Therefore, given that IWT takes place amongst human social, historical and cultural relations, I conceive it as a social phenomenon in and of itself, influenced by norms dictated by nationality, culture and religion, and mediated by social differences such as gender, race, age inequality or class (Margulies et al. 2023).

There are two components of IWT's wickedness that I explore in this thesis, contentions around legality and sustainability. Many IWTs fall into unregulated grey areas (Dickinson 2022), often with the involvement of legal enterprises that commit green-collar crimes (environmental crimes committed by legally registered companies) (Iordăchescu et al. 2023). IWTs can be unsustainable and exert pressure on wild populations from over-extraction (Hughes et al. 2023; Marshall et al. 2025). Answers to these goals will be more or less palatable to relevant parties (trade actors like harvesters and vendors, policymakers, conservation organizations and local communities affected by and participating in IWT). It is evident that conservation needs an interdisciplinary or transdisciplinary approach to treat and understand IWT as a wicked problem.

Though historically wildlife trade has been a subject of research in the field of conservation biology, this thesis engages with the interdisciplinary traditions of conservation social science, drawing heavily on elements of political ecology. Political ecology, a subfield of critical geography, has been increasingly applied as an approach to studying wildlife trade, to help understand the broader context of trades on ecosystems, species, and humans (Duffy and Massé 2023), i.e. accounting for trade as a social phenomenon. Beyond unhelpful binaries of (il)legal, (un)sustainable and (il)licit, green criminologists and political ecologists have made extensive progress in characterizing the heterogeneity in IWTs. There are multiple complexities and conflicts between the *de jure* (according to law) and *de facto* (what happens in practice or reality) enforcement of wildlife trade rules. A wildlife trade can be socially legitimate or licit to local people, even if it is *de jure* illegal (Brombacher et al. 2021). A term that captures this complexity is Hübschle's (2017) concept of a "contested illegality", where the lines between legal and illegal activities are blurred since individuals perceive the laws as illegitimate or subordinate to other customary frameworks.

1.1.2. Why do individuals matter in the wildlife trade?

Political ecology has been criticized for not considering the more-than-human (which Lorimer and Hodgetts (2024) define as the interconnectedness of human life with non-human entities, like animals, plants and technologies), and failing to account for the agency and experience of non-human animals (Srinivasan and Kasturirangan 2016). It is unclear where wildlife (e.g. animals and plants, alive or dead) fits into the wildlife trade.

What has been explored less is issues of agency, rights, and welfare of animals in the wildlife trade. Research is still lacking on the scale and nature of (animal) suffering implicit in these systems (Hutchinson 2023; Pons-Hernandez 2024), nor on the underlying structural drivers of IWT (Duffy 2022). An explicitly more-than-human political ecology could 'offer particular perspective(s) on human-non-human encounters and the worlds they co-produce while recognising their contingent and fragile nature' (Greenhough 2014, p.115), in addition to the traditional modes of political ecology analysis that understand how questions of power shape human-nature relationships. Understanding the individual's experience and the potential harm they experience may, in turn, reveal more about the structure of trade and how human actors become entangled in it.

Remsen (1995) claimed that individuals are not 'the fundamental unit of concern for conservation biology', rather the normative commitments of conservation biologists are to care for species and their habitats (Campbell 2012). However, it is now better acknowledged that 'animals have interests, desires, thoughts, feelings, and points of view concerning what happens to them' (Lappe-Osthege and Duffy 2024). Rose, Dooren, and Chrulew (2017) argue that the loss of an individual of a species is a 'double death', that obliterates past and future generations.

The rise of multispecies ethnography has brought significant attention to the relationships between humans and non-human animals. Multispecies ethnography has answers to both political ecology's human exceptionalism and conservation's rigid species logic by acknowledging animals as individuals as well as populations, understanding their subjectivity and why it matters (Kirksey and Helmreich 2010). Broadly, there are two types (Tomlinson 2020); the first is recognising the agency of non-human entities (animals, plants, but even inanimate objects, like when plastics form plastic-creatures with marine animals (De Wolff 2017)), where agency is qualified as the power or ability of an entity to actively shape processes and lives. The second type treats non-human animals as intersubjective, individual actors who experience pain and emotions. Multispecies ethnography can form part of a harms-based approach to wildlife trade that centres on the non-human individual victims of wildlife trade (Wyatt et al. 2022; Hutchinson 2023), both in terms of animal and plant species.

1.1.3. Interventions to IWT

Interventions that address IWT to mitigate potential negative impacts on wildlife and human livelihoods can be broadly grouped into supply-side actions, trade controls and end-market actions (Öckerman et al. 2024). These three pathways align with the areas of interventions that IWT prevention funding is often directed to, protected area management (supply-side, 46%), law enforcement (trade controls, 19%), and sustainable use and alternative livelihoods (supply-side or end-market, 15%), as reported by Roe and Booker (2019). However, given that there are no 'perfect solutions' in terms of wicked problems, I view these interventions as partial or imperfect solutions to

IWT (Termeer et al. 2019). These interventions are further complicated by the fact that many people view IWTs as contested illegalities (Hübschle 2017).

Mainstream interventions in IWT do not always appreciate the wickedness of IWT, nor acknowledge the wildlife product being traded as a subject and an actor. Bearing these things in mind, I focus on one pathway of intervention, trade controls, that aim to increase trade enforcement and compliance (Öckerman et al. 2024). Key interventions in this pathway are the 'Detection and enforcement of trade laws, policies, and codes' and 'Prosecution of trade violations' (Öckerman et al. 2024).

IWT issues are increasingly tackled with enforcement-first approaches (Duffy and Massé 2023), becoming reliant on trade controls for easy and visible wins. To do so, conservation efforts increasingly rely on police power to combat illegal activities like poaching, a phenomenon which Massé (2022) terms the 'police power in green'. There are several concerns around the integration of policing methods into addressing IWT. Thus, IWT becomes criminalized, and part of the wider criminal justice system (laws and institutions that manage crime) (Adhiasto et al. 2023). Policing practices include the use of punitive methods such as surveillance (Simlai and Sandbrook 2021), fines and arrests that extend to the carceral (prison time) (de Jong et al. 2024) and the fatal (use of shoot-to-kill policies against hunters (Lunstrum 2014)) and are largely engineered by shifts to viewing wildlife trade through a criminal lens.

The conservation literature often contains critiques of lax or unconcerned conservation law enforcement (CLE), the practices and authorities enforcing biodiversity laws and regulations (Massé 2020)), though it is unclear how accurate these critiques are. Much of the existing research focuses on the experiences of rangers in source areas for wildlife, around interventions in the supply-side pathway. For instance Massé (2020) conducted an extensive ethnography with anti-poaching personnel in Mozambique. However, there is less attention on those engaging with the realities of both legal and illegal wildlife trade at the end-market, for instance, members of local agencies and customs staff who are tasked with policing sites of trade or apprehending consumers in urban areas. Runhovde (2022) argues that gaps between official policies and daily work activities within organizations, compromises policing of IWT, and she argues that policing should focus on particular places like ports of entry and transit consignments.

1.2. The problem of species identification and the use of technology for species identification

As I have outlined, there are numerous challenges that complicate the enforcement of IWT and make it a wicked problem. At the heart of this thesis, I look deeper at one facet: species identification. Species identification is a major challenge in successfully conducting trade enforcement and compliance, which uses national and international regulations to identify IWT. Detecting extinction or species decline (or the reverse, understanding the sustainability of a trade) is complex (Alfino and Roberts 2019) when even identifying the species may be difficult (i.e. when visually similar species or a multitude of species are sold). Species misidentifications or lack of identification can lead to underestimating species richness and volume at markets and confound the detection of illicit trade (Alfino and Roberts 2019). Species identification, in wildlife trade research and broader ecological studies historically has been done by human skill, which may be individual or communal knowledge and may lie within or outside of the communities responsible for enforcement.

Recently, identification methods have adapted to take advantage of emerging technologies in conservation. A subset of these technologies are IWT technologies, which I define as tools designed to support conservation law enforcement and other users like conservation practitioners and members of the public in combating wildlife trafficking. At their core, IWT technologies enable surveillance-style monitoring for law enforcement derived from military intelligence. IWT technologies are appealing because they support punitive interventions (Hu et al. 2023) aligning with the dominant view of technological determinism in conservation (assuming that technology will positively impact conservation). In the broadest sense, IWT technologies can include tools like airport X-ray machines, genomic analyses, and custom-built taxonomic aids for species identification. These tools are designed with the aim of helping enforce biodiversity laws and regulations by improving the detection and identification of trafficked species.

Here we consider the subset of IWT technologies used for species identification explicitly. Before the advent of artificial intelligence (AI, a set of technologies that can imitate intelligent human behaviour (Clifton et al. 2020)), IWT technologies were focused on mobile phone apps, using decision trees to arrive at an identification, with apps doubling as opportunities for end-users to report wildlife crime (e.g. the WildAlert application (Kretser et al. 2015)). Over the last decade or so, substantial advances in computing power and increasingly sophisticated algorithms have enabled researchers to process massive amounts of unstructured data (Clifton et al. 2020). Optical recognition approaches using machine learning algorithms (a form of artificial intelligence) to assist with a range of tasks to assist with the process of species identification. Technologies fulfil tasks such as visual species identification (e.g. the FinFinder app (ConservationXLabs 2022)), data mining (text-based approaches used by Lavorgna et al. (2020) and Stringham et al. (2021)), data sorting (e.g., Fink et al. (2021) and Kulkarni and Di Minin (2023) and determining between the provenance and authenticity of wildlife products (e.g. for tortoiseshell, The SEE Turtles app (2022)). The evaluation of technological interventions in wildlife trade is relatively non-existent in the academic literature, even though artificial intelligence is increasingly being used to monitor IWT for various purposes.

1.2.1. The landscape of technology for tackling wildlife crime

Within the arena of policing and law enforcement in general, technology has become increasingly used for crime detection, prevention and convictions. The development and widespread use of CCTV cameras has created technology-based surveillance (Chambers 2007). Simlai and Sandbrook (2021) note that many of the devices currently used in nature conservation were originally developed for surveillance and law enforcement, for instance, the CCTV camera becomes the panoptic drone to monitor wildlife and surveil the people who live alongside and rely on wildlife for their livelihoods (Simlai and Sandbrook 2024).

The trend of integrating artificial intelligence (AI) techniques into the arsenal of responses to tackle wildlife crime is possibly due to persisting patterns of increasing demand for wildlife (Marshall et al. 2025) and a lack of capacity to enforce conservation laws (Gluszek et al. 2021). Alternatively, the shifts to using AI can be seen to conform to the ‘security turn’ that has been adopted by conservation and IWT policy (Duffy 2022, p.191).

1.2.2. Ethical risks of using IWT technologies

There are a multitude of ethical concerns for humans (end-users, subjects) and wildlife that muddy the introduction of technology into enforcement systems. In terms of subjects of the law, using visual technologies could lead to 'human bycatch' where images of people are accidentally captured, for instance, on camera traps (Sandbrook et al. 2021). Monitoring could be specifically targeted at people like offenders (Verma et al. 2016), placing them under surveillance without their consent (Sandbrook et al. 2021; Simlai and Sandbrook 2024). Algorithm-driven interventions may target individuals (Duffy 2022, p.142) and be trained with racial bias.

In terms of end-users, the use of technologies could add further to the stress of conservation law enforcement officers, which has been well documented around issues of low pay, isolation and risk at work (Oliver 2006) and may make CLE feel like they themselves are policed as they work (Kuiper et al. 2025). People working in enforcement or conservation may be relegated to supporting rather than participatory roles if technologies take centre stage (Verma et al. 2016). In terms of using conservation technology as a taxonomic aid, there are also risks of deskilling taxonomists, who are already declining in number and whether the accuracy of identifications generated by computers can be trusted (Campos et al. 2024).

In online wildlife trade, actors can circumvent surveillance technologies for instance uploading black and white or distorted images to social media marketplaces (Hernandez-Castro and Roberts 2015). In physical trade, the use of surveillance technologies may have unintended consequences for wildlife, for instance if trade becomes more clandestine or if animals are physically transformed to evade detection (for instance spray painting birds assorted colours). Finally, there also needs to be consideration for the vast amount of e-waste generated from machine learning (Arts et al. 2015) and some recent concerning statistics on extreme water usage from generative AI (Sandbrook 2025).

1.2.3. The future of IWT technology research

Given the risks of using technology, it is evident that more research is warranted to determine if it can be a useful tool in the toolbox of IWT prevention techniques, and if it is socially and ethically appropriate and culturally accepted. Participatory design has been suggested to adapt to cultural ways of working, for instance, building on the Information and Communications Technologies for Development (ICT4D) movement, which uses technology to help people with a broad range of challenges relating to agriculture and health in 'developing countries'. The ICT4D literature often highlights that technology fails from top-down design processes in other sectors, like health and agriculture (Steinke et al. 2022).

We can inspiration from various ICT4D projects in the Global South that have used equitable and postcolonial participatory design processes to better engage with marginalized communities. Lewis (2012) designed an offline, symbol-based user interface with non-literate hunter-gatherer communities to track illegal logging in Congo, charging phones using a thermoelectric generator that converts heat from a cooking pot into electricity, all with the aim of preserving local people's hunting rights.

The Map Kibera Project engaged with local people living in the Kibera slum in Nairobi. Local residents of Kibera were trained to use GPS devices to create a thorough map of their community (Koletis 2022, p.8). The project also used texts, online videos and blogging to provide local news services and highlight community perspectives. Maps showed up-to-date local amenities for residents and healthcare workers, such as pathways, clinics, water points, and markets (Koletis 2022, p.12). Taking inspiration from the ICT4D literature on technology design processes could increase the effectiveness of technology-enhanced trade control interventions by providing CLE with the means to identify IWT faster and more reliably (Royal Society 2018). Conversely, critique of the ICT4D sector reveals uneven politics, a neoliberal bias, techno-optimism, and a Eurocentric perspective (Schelenz and Pawelec 2022). These technologies often fail to deliver tangible benefits to the intended beneficiaries.

This thesis addresses IWT as a wicked problem, though I focus on the specific pathway of intervention (i.e. trade controls), I address other components of wickedness that are revealed in this method. The fundamental role of a technological intervention (i.e. legalistic) is to make enforcement possible (by providing an option for automated species identification), not to convince people not to engage with IWT in the first place. Still, the holistic nature of these conservation technology design methods may help to respond to wicked problems; I pick at one thread (technology), see what happens, with a view to learn about the wider knot of the problem (IWT) to provide partial solutions to reduce or prevent IWT. By placing technology in the social and cultural contexts where IWT takes place, I learn about other components of wickedness that may or may not affect the possibilities of using IWT technologies. Further, this thesis seeks not to moralise wildlife trade but to highlight the social complexities around it.

1.3. Case study: Asian songbird trade

One type of IWT that is particularly complex and somewhat understudied is (il)legal bird trade across Southeast Asia. The species diversity of bird trade is comparable to other trades like for reptiles, amphibians (Bush et al. 2014), plants (Margulies et al. 2023) or insects (Fukushima et al. 2021). The centre of this trade is in Indonesia, where a multitude of practices entangle birds for use as pets, food, for entertainment, decoration or omens (Marshall et al. 2019; Miller et al. 2019). Most notably, on the island of Java, there are deep-rooted traditions of keeping birds at home derived from royal nobility (Pradita and Wardhana 2021). Birdkeeping is also seen as reinforcing visions of Indonesia's Golden Age (Planet Indonesia 2022), and as a means of connecting to and reclaiming Indonesian culture post-independence (Thomsen et al. 2024). Birdkeeping practices dispersed across the archipelago due to government sanctioned Javanese transmigration programs (Indraswari et al. 2020). Consequently, there are now hundreds of bird market hubs across Indonesia (Lowen 2016). The most diverse and arguably famous is the Pramuka marketplace in Jakarta, established in the 1970s (Chng et al. 2015), though there are sizeable markets in Eastern and Central Java (Chng and Eaton 2016), North Sumatra (Shepherd et al. 2004), Bali (Chng et al. 2018), and West Kalimantan (Rentschlar et al. 2018).

The cage-bird trade in Indonesia is a prime example of a contested illegality, as most trade is illegal yet happens mostly in the 'open'. Shepherd and Leupen (2021) note that birds are protected under Indonesia's conservation law, and openly sold in violation of that, or they are unprotected, with their wild harvest monitored through an annual quota system. In TRAFFIC's 2015 survey of major marketplaces in Jakarta, 98% (18,641 birds from 184 species) were estimated to have been harvested outside of the quota system or in direct violation of the Conservation Act (No. 5) of 1990 (law since updated) (Chng et al. 2015).

When I refer to the songbird trade, I follow Mirin and Klinck (2021), who define songbirds as both passerines and non-passerines, including junglefowl, barbets and doves that are also appreciated for their songs. Bird trade forms part of a complex IWT ecosystem, valued by Indonesia's Environment Ministry at IDR 13 trillion (GBP 634,085,400) (United Nations Development Programme 2020). There are two concurrent supply chains for birds in Java (the hotspot) of varying lengths (distance from source to consumer), one long, which is high-volume and low-worth, and the other short; low-volume and high-worth (Jepson et al. 2011). In these chains, at least 500 species are circulated (Fiennes et al. forthcoming), and ownership ranges from up to 80 million birds in captivity on Java (Marshall et al. 2019), to 170 million across the wider archipelago (Nuruliawati et al. 2023). A 2018 estimate suggested that 1 million birds are trapped a year (People Not Poaching 2018), whereas others estimate as many as 14 million per year (Silalahi and Sihaloho 2020). Indonesia likely has the highest rates of songbird ownership in the world, followed by Brazil with an estimate of 42 million (Polo 2023). The Indonesian songbird trade is worth IDR 1.65 trillion (GBP 79 million) annually (Office of Assistant to Deputy Cabinet Secretary for State Documents & Translation 2018), including the feed, cage, vitamins and medicine sectors. However, recent estimates suggested turnover was closer to IDR 3-5 trillion (GBP 145 – 241 million) a year (Silalahi and Sihaloho 2020).

1.3.1. What might technology be used for in this reducing songbird IWT?

The pressure on Indonesia's native avifauna has intensified since the early 2000s, since Indonesia temporarily banned the import of live birds from China and Hong Kong after the outbreak of avian influenza (Shepherd et al. 2020). Increasing demand for birds in recent years precipitated the declaration of the Asian Songbird Extinction Crisis (ASC) by the IUCN in 2017 (Lee 2016; Shepherd and Cassey 2017). Since its declaration in 2017, the ASC has potentially worsened (i.e. uplisting of more species on their priority taxa list). Deforestation is also a compounding factor in accelerating bird trade, opening up habitats and driving declines by reducing forest cover, for instance, West Java has lost 40% of its forest cover in the last 30 years or so (Higginbottom et al. 2019).

Whilst trained experts in Southeast Asian bird taxonomy exist, they are rare and unlikely to be present on routine surveys conducted by law enforcement. Studies have reported a range of 25 – 36 percent of birds in markets and seizures as unidentified to species level (Rentschlar et al. 2018; Indraswari et al. 2020). New species have appeared in trade even during the onset of the COVID-19 pandemic (Armstrong and Chng 2020). Further, the latest iteration of the Conservation Strategy of the IUCN Species Survival Commission (SSC) Asian Songbird Trade Specialist Group (ASTSG) has been widened to accommodate greater pressure on more species, and several species have been uplisted by the IUCN in terms of their conservation status and moved higher on the CITES Appendices (CITES 2023).

Other studies across East Asia have shown that enhanced law enforcement efforts at bird marketplaces constrict market volume and diversity and lead to less protected species sold over time (Fiennes et al. 2021). However, the assumption that law enforcement presence is an effective deterrent in the Indonesian context has been questioned. Some studies have claimed that law enforcement is not an effective feature of Indonesia's bird trade system, embodied by weak governance and rampant corruption (Nijman et al. 2018). Several researchers have called for more effective law enforcement and prosecution of lawbreakers as solutions to the Asian Songbird Crisis (Shepherd et al. 2016b; Shepherd and Cassey 2017; Nijman et al. 2018), and this is a common response for many other IWTs.

Simlai and Sandbrook (2021) stress the importance of not seeing the integration of digital technologies in conservation from a good-bad binary perspective, nor do I assume that law enforcement is a homogeneous group of disinterested and corrupt individuals. Building off broader calls for more technology-related IWT interventions (Royal Society 2018), and focusing on the issue of species identification, this thesis seeks to explore the nuance of technology use in preventing and reducing IWT. I argue that the songbird trade is a prime case study through which to explore a technology-mediated trade control intervention around species identification, the appropriateness of these interventions in terms of the social and cultural contexts of use, and their potential effectiveness in reducing IWT.

1.4. Research strategy and structure

The primary notion this thesis considers is, given the social praxis *de facto* for law enforcement – where does technology *fit* in terms of tackling IWT? If technology were to be used to tackle the issue of species identification in the songbird trade in Indonesia, where would it fit? Does it fit? Are there other interventions that could be considered bearing IWTs wickedness in mind?

In answering this overarching question, I anticipate the tackling of IWT as a legal issue (involving the right laws), a technical challenge (right technology and tools) but also as a social process (the muddled *de facto* reality of IWT enforcement, of stressed, limited, potentially corrupt, or undertrained conservation law enforcement, and the actual lives and actions of trade actors and birds, and the system they are embedded in).

My approach is necessarily qualitative to understand the role of technology along social and ecological dimensions, which in my case study includes acknowledging birds as subjective actors, as well as understanding law enforcement practices from the perspective of the enforcer, which is poorly understood.

There is a sequential structure to this thesis, with a series of nested questions that engage with the multiple facets of IWT (social, technological and ecological dimensions) that have been identified here as of interest. Through the technological, it is possible to learn more about the social and ecological dimensions of trade. In between each data chapter, I add an interlude as a reflection on the chapter and how this shapes the following chapter. As part of a technology assessment, I ask the following questions, with the overarching questions in italics:

1. *Are optical recognition approaches feasible*? How effective are automatic machine learning technologies (artificial intelligence) in identifying birds in the Southeast Asian songbird trade, particularly in complex environments? What are the

limitations and potential improvements needed for image-based machine learning approaches to accurately identify birds from occluded wildlife market photos?

2. *How is conservation law enforcement (CLE) structured and what means do they use for enforcement?* What are the challenges faced by CLE agencies in distinguishing legal from illegal bird trade in Southeast Asia? Is there a role for taxonomic aids?
3. *What do conservation law enforcement officers think about technology and its role in their work? If technology has a role, how can it be designed to fit into the work of law enforcement?* In what ways does a participatory, user-centred design approach to technology design change the uptake or success of technologies?
4. *Given that current conservation debates position IWT as a serious and urgent issue, how is songbird IWT perceived in local contexts versus in global conservation?* What are the implications of labelling species decline as a 'crisis' for conservation efforts, using the Asian Songbird Crisis (ASC) as a case study? How is the ASC perceived by different stakeholders, particularly conservation law enforcement and practitioners?
5. *How can wildlife be centred in wildlife trade?. How can the harms to animals in the wildlife trade be better understood and what does this tell us about the unique social and cultural contexts of trade?* How does the Indonesian songbird trade impact the welfare of birds, considering the cultural, economic, and ecological dimensions of the trade? What are the key power dynamics and interactions between human and nonhuman actors within the Indonesian songbird trade? How do class, gender, and cultural issues influence the harm experienced by birds in the wildlife trade?

In **Chapter 2**, I explore the feasibility of using machine learning methods to identify birds sold in Indonesian marketplaces. This chapter advances other work on using machine learning in IWT contexts and describes the methodology in detail for collecting data, training and evaluating models. I specifically analyse the performance of a convolutional neural network, a type of deep learning models for image classification that scan images for patterns and learn them.

After establishing a degree of accuracy is possible for the context of identifying songbirds in trade, I consider next the structure of CLE and songbird-related activities. **Chapter 3** comprehends that species identification capabilities can be a limiting factor in the efficacy of songbird-related law enforcement. In this chapter, I describe the role of law enforcement within this system, probing motivations, understanding processes, and categorising a spectrum of responses to bird trade among law enforcement.

Based on discussions with CLE about the potential for taxonomic aids in their work, I then went on to explore what such technology could look like in practice, considering the use of more participatory design methodologies. The relationship between technology, laws, and law enforcement personnel is not linear but a complex web of relationships, which is what might be expected from a wicked problem like IWT. In **Chapter 4**, I analyse how technology interacts with the social worlds of conservation law enforcement (CLE), the people and how it might influence CLE, the practice. Assessing if and how technology could be integrated into songbird law enforcement is important, thus I use a co-production/ participatory design methodology to assess a robust prototype of an image-based species identification technology for tackling (il)legal songbird trade, for use in countries affected by the ASC. The combination of design theory and end-user experience research techniques allows me to outline methodological innovations for participatory, co-creative approach to conservation technologies. Additionally, I examine use cases for technology, considering NGO attitudes towards law enforcement (which may indicate lack of interest or usefulness) and compare them with law enforcement's self-perception.

In doing the focus group discussions and user centred design sessions in **Chapter 4**, I found that users of the proposed intervention had not heard of the ASC, even though it is part of the everyday language of conservation organisations. This inspired the fourth chapter on crisis narratives and led me to ponder how conservation thinks about species. In **Chapter 5** I explore the ASC, declared by the IUCN. My research investigates how different actors, particularly conservation law enforcement and practitioners, perceive bird extinction and the ASC in Indonesia. This chapter highlights the need for a shared language around species extinction and the unsuitability of the 'crisis' label to describe unsustainable bird trade.

Interactions with CLE my experiences in bird marketplaces, and discussions with academics and conservation practitioners all revealed wider elements of the bird trade system that have not been reported in the academic literature. As a result, I close the previous data chapters with an updated and more nuanced perspective on Asian songbird trade that incorporates insights from a more-than-human political ecology approach. To bring together these insights, **Chapter 6** addresses the songbird trade, in Indonesia, through a more-than-human political ecology lens. Historically, conservation has focused on the 'problem' of wildlife trade, often neglecting the welfare of traded animals and plants. My study employs marketplace observations, one-on-one interviews with experts, and focus groups with law enforcement to map the trade across three levels: actor, inter-actor, and market. I use an intersubjective multispecies ethnographic approach to attribute agency to birds and acknowledge their subjectivity. Understanding class, gender, and cultural issues is crucial to addressing the harms faced by traded birds.

My general discussion (**Chapter 7**) considers each chapter and its learnings in turn and asks what strategies can be developed to manage the bird trade more justly and effectively (at the individual level in terms of harm and safety and the population level, in terms of species diversity and sustainability), following a socioecological harm reduction approach. The thesis is presented as a series of journal articles in various stages of review. I have reproduced the content as submitted to journals and, as a result, the data chapters (**Chapters 2 through 6)** use "We" rather than "I" " Further, along the way I produced some extra outputs that are not in the thesis, but are relevant, seen in Appendix 6.

1.5. Thesis contributions

This thesis has generated valuable insights about the social, cultural and economic elements of human-wildlife interactions to enrich our understanding of how people fit into natural systems and how nature then moulds around us. The central contribution of this thesis is that it foregrounds the design and implementation process of technology to interface with wicked problems, using a socio/political/technical framework to understand a case study from the Asian Songbird Crisis in Indonesia, the global hotspot.

Verma et al. (2016) argue for reflexivity in examining the intentions informing the use of technologies for nature conservation, as well as in considering the consequences of deploying technology. In the same vein, I add that reflexive approaches to wildlife trade are needed; thus, this thesis contributes two framings to the conservation-focused literature.

Framing 1: Co-Productivist and Participatory Design - **Chapters 3 to 4** consider a participatory methodology for technology assessment that involves engaging end users in the design process, what I call a co-production (CP) and participatory design (PD) approach. This is a methodology for assessing technological interventions that include as a priority the local socio-political context of IWT, and how both humans and technologies mutually affect each other.

Framing 2: More-than-human political ecology - The scale of the Indonesian bird trade is examined through a political ecology and multispecies ethnography approach to develop an understanding of the harms birds face in **Chapter 6.** This approach consolidates a more-than-human approach to wildlife trade.

The wider application of this work will contribute to conservation science, sociology and design studies by highlighting the value of blending disciplinary approaches to provide an account of a holistic technology assessment to address a wicked problem such as the rising bird trade in Southeast Asia. Of the outputs expected from this project, it is possible that several will have an important impact on conservation law enforcement practices and wildlife trade and conservation technology research:

1. Strong encouragement to foreground wildlife in wildlife trade, focusing on how power relations are implicated in a more-than-human approach.
2. Critical and community-led co-productivist/participatory design approach to “proper” technology development in an IWT case study. This approach can be used to show the role of technology in other conservation issues and how technology must be socially, culturally, legally and technically embedded if it is to be deployed.
3. The implications of 'crisis' narratives in IWT do not reflect local values in the case of birds trade, or are they conducive to exploring sustainable trade narrative, highlighting the need for a perspective that considers cultural and political barriers to addressing IWT.
4. Following my concerns around and the limits of technological interventions, and around punitive, enforcement-based interventions for IWT, I suggest a range of non-punitive interventions, that take their theoretical basis from a range of frameworks like socioecological harm reduction, critical environmental justice and abolitionist approaches to conservation and are based on minimizing harms to birds whilst acknowledging that the continuation of wild bird trade is likely and an important component of Indonesian identity.

The thesis concludes with a critical reflection on punitive versus non-punitive approaches (a taxonomic aid would be part of the current enforcement system, which is rooted in punitive methods). Though direct, punitive law enforcement methods are not relied on in the case of songbird IWT, the recent increase in the criminalization of IWT in Indonesia may suggest otherwise (Yulisman 2024). Technology design (i.e. using the user-centred design) with end-users to develop taxonomic aids more equitably does not fix the broader problems with enforcement-first approaches to IWT. I suggest roles for technology in decriminalised or legalized songbird trade governance scenarios with more of an emphasis on traceability and sustainability. Abolitionist approaches are a logical consequence or emerge from my critique, especially when also taking together the reservations of CLE around punitive methods, the high rates of songbird IWT recidivism and the need to reduce harm to individual birds and their populations.

1.6. Positionality statement

As someone previously trained in conservation biology and having developed my machine learning skills during my master's, I naively thought at the onset of this thesis that this would be the culmination of these skills, disciplinary knowledge and a flavour of extinction studies, the subfield shaping my DTP program.

Thinking this was a primarily conservation technology-style research project (a tame problem, logical fix), I initially started with an exploration of design theory, looking to behemoths of the field like Don Norman (2013) on *The Design of Everyday Things* or Steve Krug's (2013) *Don't Make Me Think* on usability and user experience. To engage with conservation law enforcement in creative ways, I relied heavily on the Helens; Helen Newing (2010) *Conducting Research in Conservation: Social Science Methods and Practice* and Helen Kara (2015) *Creative Research Methods: A Practical Guide*.

Prior to going on my fieldwork, I started to panic and wonder if my idea would fail, what if my participants hated the idea of a species identification technology? In doing so, I started to consider a broader flexible approach, one that would consider the social worlds and ways of working of conservation law enforcement, thinking how could I alter my methodology to allow space for other (partial) solutions to emerge? One possibility could be that technology is the right solution.

I had always been interested in political ecology and had initially considered incorporating qualitative methods (i.e. focus groups), which meant I was doing a conservation social science project as well as a conservation technology design project. However, as I got deeper into the project, I realized that a political ecology approach is a fascinating way to interrogate power structures that govern human-environment problems, tensions and politics. Conservation biology alone is necessary but not sufficient to understand human-animal relations. There are several other ways to study human relationships with animals, ethno-zoology (or ethno-ornithology (e.g. Tidemann and Gosler 2010)), animal studies and more, though none felt suitable for this project in terms of understanding this unique case study and how individuals and species are harmed by wildlife trade.

As I got deeper into thinking about my positionality and how to acknowledge my various privileges in relation to the people I would be speaking to and writing about, I dealt with my own personal avoidance of aspects of myself that had been under-explored. Bird trade in Indonesia is a gendered trade particularly around the performance of cisnormative and Javanese versions of masculinity.

As I pondered on how people would perceive me as a white person from the UK, assigned female at birth, I came to understand myself more as a gender-nonconforming person. Now I know where I fit, under the nonbinary umbrella as a gender-neutral (agender) person.

This was a major catalyst in my personal and professional life, and I started to more fully embrace the fact that the personal is political (a term first coined by Carol Hanisch). Though it was a deeply painful experience for me to go back in the closet and accepting I would be perceived as and treated as a cis woman on fieldwork, I found joy in acknowledging that personality sits alongside positionality (Moser 2008). I learnt valuable insights about gender, bird trade and male socialization chatting about football with bird traders. These were euphoric moments for me, not only chatting about one of my hobbies but also felt like I was being seen as a football fan first. Even though visiting marketplaces was traumatic at times and stressful in sensory and emotional ways regarding the conditions animals were in, I was morbidly fascinated by the diversity of bird species, and then, every now and then, my favourite football team would pop up. Learning Indonesian or looking at abolition frameworks meant that, in some sense, I was not approaching research subjects (both people and birds) with a neo-colonial mindset in the first place. Learning Indonesian also helped with developing a more decolonial approach to research, alongside my plans to feed back to the local communities and philosophies of reimbursement that pervade the whole project.

My visits to marketplaces also led me to important considerations and parallels around the caging of birds and the response of carceral conservation to imprison people (de Jong et al. 2024). It is impossible then to say that this project is not a queer and specifically gender queer perspective of trade. As I came to see gender as a spectrum I tried to let loose other binaries in my life and research.

This project is still inspired by conservation biology, a discipline I have been engaged with since my first fieldwork experiences in 2015 and was motivated initially by my own environmental concern about the sustainability of wildlife trade, and particularly bird trade, the subject I knew most about. Conservation biology helps us think about the ecological dimensions of wildlife trade at the population level, political ecology and conservation social science help us think about the *human* social, and somewhere between these two, multispecies ethnography helps us to get close to thinking about the individual non-human entity (whether animal, plant or inanimate object) that bridges the social and ecological. Finally, conservation technology and design theory help us understand the role of technology, but it is only the combination of the other disciplines that help us to appraise or assess if technology is really needed in its specific social and cultural context. This also allows us to embrace or consider other possibilities for reducing harm to people and wildlife.

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Chapter 2. Feasibility of image-based machine learning for identifying bird species in wildlife trade

2.1. Abstract

In Southeast Asia, songbirds are highly valued for singing contests, breeding, religious ceremonies, and as pets. Due to rising demand for wild-caught birds, the International Union for the Conservation of Nature declared an Asian Songbird Crisis in 2017. Species identification due to the high species diversity is a central challenge. Applying machine learning technologies represents one potential solution for visual identification. While prior work has demonstrated image recognition's potential in bird identification, it is uncertain if image recognition applies to occluded wildlife market photos (e.g. birds behind cage bars). Here, we focus on the image classification of birds sold in cages in the Southeast Asian bird trade from multi-sensor image types (various mobile phones and cameras). We collated a dataset representing 56 species traded across Southeast Asian wildlife marketplaces. The best model achieved a moderate top one accuracy (67%) for 46 of the 56 species (correct label predicted in the first guess) and 87% for the top two accuracy (one of two guesses contained the right identification) on a test set unseen during training. Following improvements in these results, such a tool could provide strategic support to Indonesian authorities, specifically natural resource agents and quarantine officers. This work could help overcome previous roadblocks by using machine learning to identify birds from pictures in wildlife marketplaces. Image-based machine learning approaches are promising for identifying birds and other taxa in highly occluded trade environments.

2.2. Introduction

The legal and illegal wildlife trade (IWT) are multibillion-dollar industries. Both pose a significant conservation issue involving hundreds of thousands of animals, plants, and fungi (Phelps et al. 2016). In general, the magnitude of the global wildlife trade warrants more approaches to tackle IWT at speed and scale, especially to keep up with rapid market dynamics. Species identification is essential to confront IWT, but it is often undervalued. Misidentification or lack of species identification (particularly in highly diverse trades or those comprised of similar species) hinders accurate harvest estimates and the detection of illegal trade (Alfino and Roberts 2019).

Unaided species identification requires taxonomic training uncommon in local agencies (Gouda et al. 2020), which form the frontline of law enforcement. Without effective species identification, law enforcement often faces delays and errors that complicate IWT handling. Automatic, computer-aided species recognition approaches may lower misidentification rates and generate useful, actionable intelligence for law enforcement as well as data on the turnover of species in trade that is vital to understanding IWT trade dynamics (Bušina et al. 2020).

One wildlife trade that suffers from low species identification capacity, particularly amongst law enforcement, is the songbird trade in SE Asia (Guciano et al. 2024). Birds are highly sought after in this region for singing competitions, religious practices, breeding and pets. This trade is complicated, embedded in culture and history, and largely considered to be socially acceptable within the region (Fiennes et al. 2024). Thus, better species identification may offer a partial solution to a highly complex problem. Whilst species identification contributes towards a solution, other factors also need attention.

At least 500 species of bird have been recorded in Indonesian trade in the last 10 years (Fiennes et al. forthcoming). The demand for these species taxes local populations, with at least one species considered extinct and 26 classed as a "conservation priority" as a result of trade-related population impact (Asian Songbird Trade Specialist Group 2022). The fact that those at the frontline of bird trade (i.e., law enforcement) do not have adequate capacity or technology to identify illegally traded species from the legal ones becomes an issue that requires an interdisciplinary approach.

Current identification techniques present significant challenges in many cases of taxonomic assessment. This is especially pertinent when assigning morphologically similar (cryptic) species which are often difficult to differentiate between in wildlife marketplace surveys (e.g. Zosterops spp., the White-eye family). The results of these challenges are exhibited with 25-36% of bird species recorded in marketplace and seizure research found to be unidentified at the species level (Rentschlar et al. 2018, Indraswari et al. 2020). Additionally, traditional direct census methodology does not incorporate confidence levels in species classification (Bušina et al. 2020). The use of machine learning can address these issues with the possibility of differentiating between cryptic species and reporting confidence levels in taxonomic assignments.

Machine learning, a subset of artificial intelligence (AI), aims to map inputs (data) to outputs of interest (a predicted class or identity) by applying certain algorithms (Wäldchen and Mäder 2018). Since roughly 2014, image classification has been dominated by convolutional neural networks (CNNs) (Willi et al. 2019). Broadly, CNNs consist of convolutional layers, nonlinearities, and pooling layers; convolutions act like filters scanning for patterns (edges, textures, shapes) in an image; nonlinearities, or activation functions, are applied to learn more complex relationships in the data; pooling, meanwhile, is meant to make the network more robust to small shifts by summarizing the most relevant details (Christin et al. 2019, Beery et al. 2019).

Artificial intelligence (AI) has already been used in various ways to intervene in IWT. AI-based technologies have been used to detect illegal sourcing and supply of wildlife using imaging technologies (e.g., satellite, thermal, and radar), drones, and acoustic tools to hear illegal extraction (i.e., gunshots from hunting or chainsaws for logging forests) (Lahoz-Monfort and Magrath 2021). Natural language processing (a type of AI that allows computers to understand human language) has become more widely used for web scraping to analyse what species are being traded in the wildlife trade (Stringham et al. 2021, Okarda et al. 2022). However, the use of images for identifying species in the wildlife trade has lagged; the rare exception for multiclass (many species) identification is the FinFinder tool for identifying shark and ray derivatives (ConservationXLabs 2022).

To understand benchmarks for the image-based classification of birds, we look to the existing machine-learning literature to explore the capability of deep-learning models in identifying birds using transfer learning. Using a small number of images of Himalayan birds taken at range, Das and Kumar (2018) performed a supervised classification of 16 birds, with a maximum training accuracy of 93.96% found using the CNN model Inception V3 on cropped images. Adhikari et al. (2024) employed a modified ResNet152v2 model to classify 515 bird species from 87,874 images, achieving a 97.67% test accuracy. Investigating intra-species identification, Ferreira et al. (2020) achieved up to 92.4% training accuracy using the VGG-19 architecture to identify individuals within species across three species of bird. Thus, it is evident that machine learning can identify 100s of species of birds from different distances, on datasets of varying sizes, and at the individual level.

Fink et al. (2021) used a ResNet50 model (without further training) to identify and filter relevant sales items containing birds from Facebook posts in Indonesian bird hobbyist groups. The model was able to classify images that contained the modest subset of bird species that are included in ImageNet, but, where the cage was visually dominant, the images were categorized as a prison, shopping cart, or shopping basket. Okarda et al. (2022) utilized machine learning to categorise listings for songbirds targeted by the illegal bird trade in Indonesia, filtering online advertisements according to specified taxonomic groups and subsequently matching text predictions with images using taxonomic names. However, since this species identification relies on text from adverts, their method is not usable in physical marketplaces, as this information is often only available upon request from traders. Su et al. (2024) suggested a machine-learning bioacoustics approach could be viable to identify look-alike Zosterops species traded in wildlife marketplaces. They show that 15 morphologically similar Zosterops species can be distinguished with up to 92% accuracy (Su et al. 2024). However, we are hesitant to say this will be applicable in marketplaces since they trained using wild calls. While recordings included some background noise, wildlife marketplaces contain a greater range of background sounds, including other bird songs. This is commonly called the 'cocktail party problem' (Bee and Micheyl 2008), where target signals are difficult to isolate from background sounds. It is also unknown if songs change in marketplaces, as birds are under severe stress.

To be effective in a marketplace setting, there is a need to evaluate the performance and usability of machine learning models in real-world physical settings. We lack an understanding of whether image-based machine learning for species in the wildlife trade can be feasible for low-quality images (e.g. those that are taken on phones in wildlife marketplaces), in highly occluded contexts (such as behind cage bars, crowded in cages and boxes and so forth) and in anthropogenic settings (e.g. physical marketplaces). Scant research has been published on how machine learning and AI can be deployed in these real-world settings for species identification. This research develops a methodology for data collection, image cropping and the evaluation of species classification performance of machine learning models, across a range of species targeted by Southeast Asian bird trade. This work is one of the few applications of image-based machine learning to a multi-class live trade problem.

2.3. Methods

2.3.1. Overview

This study focuses on the classification of bird species sold in cages within the Southeast Asian bird trade. We detail our methodology in four main sections: data collection, data preprocessing, model building, and evaluation.

A process called transfer learning allows users to download CNNs trained on one set of data and adapt, or transfer, them to work on a different set of data (Weinstein 2018, Das and Kumar 2018). These pre-trained CNNs are often trained on large benchmark datasets (i.e. ImageNet, a dataset which contains 1 million images across 1,000 classes (Deng et al. 2009)). These CNNs have already learnt low-level features of images, such as the shapes and outlines of objects (Couret et al. 2020), and this knowledge can be harnessed to learn new objects of interest. The final layer of models can be replaced or modified to match the number of classes in a new target dataset. The performance of models is then judged on how accurately they classify unseen images in what is called a test dataset (Kulkarni and Di Minin 2023).

Neural networks consist of an input layer, hidden layers, and an output layer (Figure S1). The input layer receives data, the hidden layers (convolution and pooling) process using weights, biases, and activation functions to introduce non-linearity, and the output layer produces the result. This structure allows the network to learn and make predictions based on the input data. An in-depth explanation of how convolutional neural networks work can also be seen here: https://cs231n.github.io/convolutional-networks/.

2.3.2. Data Collection

The data collection process was conducted in two distinct phases:

1. **Phase One (2020-2022):** We reached out to taxonomists, photographers, and members of conservation NGOs, zoos, and museums who had expertise in monitoring bird markets and the pet bird trade. This phase aimed to gather images of birds in various trade-relevant environments, including urban markets, during seizures, and in personal collections. Additionally, we included photos from conservation breeding centers and zoos.
2. **Phase Two (2023):** Field visits were conducted across several marketplaces in Indonesia, where we acquired a substantial number of images. These visits were carried out by the first author (with other authors on some visits), who visited a series of nine marketplaces across Indonesia and acquired more photos for 33 species. The images were captured using a variety of devices, including smartphones (mostly Android, with some Apple devices) and digital cameras (DSLRs and mirrorless cameras).

2.3.3. Data Preprocessing

Once the images were collected, we undertook a comprehensive data preprocessing procedure:

1. **Labeling and Cropping**: We utilized the YOLOv5 model for object detection (Jocher 2020), which generate bounding boxes (a box used to help locate objects in images) around the birds in our input images. These bounding boxes were reviewed and manually corrected using LabelMe, an open-source data labeling tool. The images were then cropped to focus on the birds and organized into species-specific folders.
2. **Dataset Compilation**: Our final dataset comprised 6,214 images of 56 bird species, with varying image sizes. The dataset, totalling 0.795 GB, was divided into training, validation,

and test sets. We adhered to a minimum requirement of 70 images per species for inclusion in the model (22 species had between 70 and 90 images), reflecting the constraints of data availability for traded species (the image count can be seen in Figure B2).

3. **Data Splitting**: We employed an 80/20 split for the training and validation sets, resulting in 4,971 images for training and 1,243 images for validation, a ratio commonly used in machine learning projects (Zhang et al. 2022). Separate from the training and validation set, we constructed an independent test set, containing 157 images of 46 species, sourced from Sukahaji Market in Bandung, West Java, and a public iNaturalist project, and were not included in the original data collection process.

2.3.4. Model Building

Our model building process involved the following steps (note our glossary for common machine learning terms, Table B1):

1. **Model Selection**: We selected the ResNet-18 model, a pre-trained convolutional neural network known for its efficiency in image classification tasks. ResNet-18, with its 18 layers, was fine-tuned to identify bird species from our dataset. This model was chosen for its lightweight architecture and proven performance in similar classification tasks for wild birds (Potluri et al. 2023) and similar ecological identification tasks, like tree identification (Natesan et al. 2019). Kulkarni and Di Minin (2023) also tested a Resnet-18 but on a binary classification task for online wildlife trade data (image containing an exotic pet or not).
2. **Data Loading**: Images were resized to 224 by 224 pixels to fit the model's input requirements. Padding was applied to maintain the aspect ratio of the images, ensuring that the birds' dimensions were not distorted (Figure B3).
3. **Hyperparameter Tuning**: We conducted a series of experiments to optimize the model's hyperparameters, including batch size, learning rate, and the number of training epochs. We used a fixed batch size of 128 and the RMSProp optimizer, with softmax activation and cross-entropy loss functions. The loss measures the difference between predictions and true labels, penalizing incorrect predictions. The model aims to minimize this loss, increasing the likelihood of correct classifications. Data augmentations were applied to enhance the model's robustness (Cardoso et al. 2023). Augmentations are modifications applied to training data to help models handle variations and improve performance. By testing and combining the best-performing augmentations, models become more consistent and transformation-invariant. The learning rate controls how fast the model learns. Learning rate

schedulers are used to gradually decrease the learning rate over time. This allows the model to make larger updates at the beginning of training when parameters are far from optimal and smaller updates later when parameters are closer to optimal. Data augmentation is a technique used in machine learning to artificially increase the size and diversity of a training dataset by modifying the existing training set imagery. Examples of modification, which we employed, include (a) rotating and flipping imagery, (b) adjusting color (lighting, saturation, and contrast), and (c) random erasing and blurring. These techniques traditionally improve the model's generalizability and robustness. In our case they mimic (a) birds at different orientations, (b) the different lighting conditions of marketplaces, and (c) occlusion, motion from birds, and motion from cameras. Each augmentation was tested individually and in combination to identify the most effective methods, ultimately improving accuracy and mean average precision (mAP).

4. **Training**: The model was trained using the training set, with performance evaluated on the validation set. Accuracy measures the percentage of correctly classified images in a dataset, with an accuracy of one indicating perfect classification, using the equation: correctly classified images in a dataset / all images in the dataset. Average Precision (AP) is the mean of precision values across all classes at various recall levels, offering a more comprehensive measure than F1 scores. The F1 score is calculated from precision and recall, rather than the top-1 accuracy or the mean average precision (measures precision at various recall levels) as it equally weighs precision and recall. We logged all experiments using the CometML platform for managing the cycle of machine learning training, allowing us to track the accuracy and mean average precision (mAP) of different hyperparameter configurations.

2.3.5. Evaluation

To contextualize our model's performance, we reference several related efforts in bird classification. The CUB-200-2011 dataset (11,788 images, 200 species) is a widely used benchmark for fine-grained bird classification. Adhikari et al. (2024) report 97.67% accuracy on 515 species, though their train/validation/test splits are not clearly described. We also compare our results to the Merlin Bird identification app, a free tool developed by the Cornell Lab of Ornithology that helps users identify birds by their appearance, song, and location. Merlin achieves 93% accuracy across 5,600 species globally, aided by user location and a much larger training set. While these tools differ in scope and evaluation methods, they provide useful context for interpreting our results.

To assess the model's performance, we used several evaluation metrics:

1. **Accuracy and mean average precision**: These metrics provided a measure of the model's overall performance in correctly identifying bird species.
2. **Confusion Matrix**: We plotted a confusion matrix to visualize the model's performance on the validation data. The matrix highlighted which species were most frequently misclassified, providing insights into potential areas for improvement.
3. **Phylogenetic Analysis**: When interpreting ML classification models, it is not uncommon to hierarchically analyze where classes succeed and fail by the model. We performed this analysis, then, as a way to understand when the model succeeded and failed, similar to how confusion matrices indicate confusion by the ML model, based onthe relationship between species, image quality, and model performance. This analysis helped us understand whether closely related species were more likely to be confused and how image quality and sample size influenced model accuracy. Using BirdTree.org, we generated distributions of trees for these species and downloaded 100 trees (Jetz et al. 2012). We then plotted one tree using a strict consensus, including only clades present in all trees. The phylogeny was plotted using the R package ‘phytools’ (version 2.0, Revell 2024) in version 4.2.2.
4. **Test Set Evaluation**: The final model was evaluated on the test set, with species identification verified by human experts. We also calculated the Top-2 accuracy, which measures the proportion of times the correct species was among the top two predictions.

2.3.6. Resources

This research was conducted using the high-performance computing facilities (ARC4) at the University of Leeds. All code was written in Python (version 3.9.0), utilizing the PyTorch library (Paszke et al. 2019) (version 1.8.1 with the Cuda library version 10.2, which allows for the use NVIDIA GPUs to speed up tasks like model training) in Microsoft Visual Studio Code (version 1.95.3), and is available in a public repository (https://github.com/CV4EcologySchool/cv4e_cagedbird_ID). Ethical approval for the use of this data was obtained from the University of Leeds (LTSBIO-039). The School of Anthropology and Conservation ethics committee at the University of Kent approved the first phase of data collection in August 2020.

2.4. Results

2.4.1. General model results

The model performs initially well on a dataset of 56 species that also includes low-quality images of birds taken on mobile phones. The best performing model used horizontal flipping as an augmentation with a probability of 0.5, a learning rate of 0.01, in addition to the fixed hyperparameters of a batch size of 128, RMSProp as the optimizer (defined in Appendix B), softmax for the activation function and cross entropy for the loss.

During hyperparameter tuning of the ResNet18 model, the accuracy for the best-performing model was 1 over 100 epochs and 0.92 for the validation data over 56 classes (species) of birds. The abbreviations used for species and the English and Latin names can be observed here: https://github.com/CV4EcologySchool/cv4e_cagedbird_ID/blob/main/species_list.pdf).

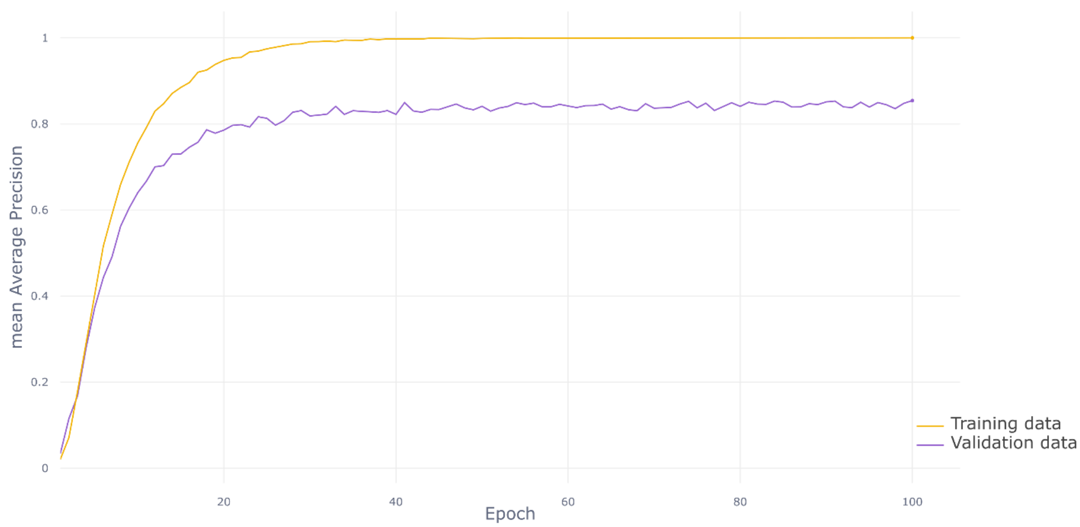

Figure 2.1: The training and validation mean average precision for the best performing model, which increased concurrently and plateaued at a score of 1 for the training and 0.85 for validation.

As mentioned before, the mean Average Precision (mAP) is the average precision (over various recall levels) for all classes in a multi-class model. It provides an overall performance summary across all species. A mAP of 0.85 shows that the model does well when dealing with a large number of species on the training and validation data (we consider 0.8 and above as good performance in a multiclass classification task such as this).

A guide to the names of the experiments can be seen in Table B2 and the visualizations of their performance can be seen in the CometML project for the study: https://www.comet.com/sicily-f/cagedbird-classifier/view/new/panels. The loss and the log of the loss for the best performing model during training can also be seen in Figure B4. In general, log loss is useful to visualize to see small changes in the loss – if the log loss shows a clear linear plot, for example, the model is still learning. The log loss for both training and validation data continue to decline during the training period (Figure B6), suggesting that the model can still learn. However, we stopped early in an attempt to prevent the model from learning unnecessary details only in the training set. From Figure 2.1, it appears that we could have experimented with stopping even earlier i.e. epoch 40-45, though we leave this as future work.

2.4.2. Confusion matrix for the validation data

Since we were unable to construct a test set with all 56 species in, we show the confusion matrix on the validation data. Confusion matrices were generated for the validation set (Figure 2.2). Species not present in the validation set are indicated with '*'.

For many species, the rate of true positives is high. In general, it seems to be that if there are misclassifications, it is with morphologically similar species (for instance, *Geopelia striata* (the Zebra Dove), was incorrectly predicted as the *Spilopelia chinensis* (Spotted Dove), on five occasions, and both have a similar body shape though differing coloration (Figure B6)) or species that are visually similar, and congeneric, like *Chloropsis sonnerati* (the Greater Green Leafbird), which was once misclassified as *Chloropsis cyanopogon* (the Lesser Green Leafbird).

Given the size of the confusion matrix, this is available as an interactive plot in html form (link: https://cv4ecologyschool.github.io/cv4e_cagedbird_ID/).

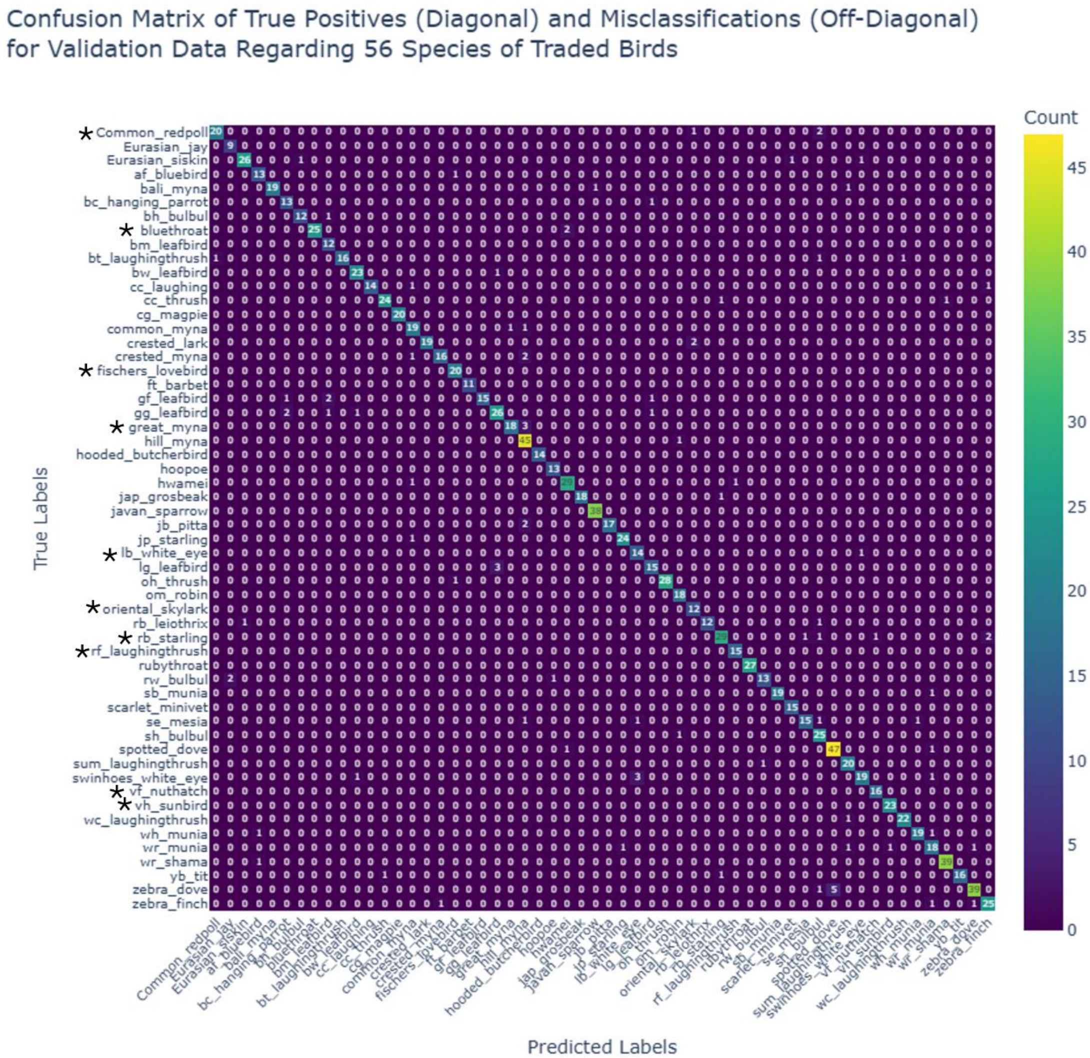

Figure 2.2: *Confusion matrix of true positives (diagonal) and misclassifications (off-diagonal) for validation data regarding 56 species of traded birds. The numerical values in the confusion matrix represent the number of predictions. Given the size of the confusion matrix, this is available as an interactive plot in html form (link: https://cv4ecologyschool.github.io/cv4e_cagedbird_ID/). Species not present in the test dataset are indicated with '*' on the axes.*

2.4.3. Phylogeny

Though the confusion matrix shows which species are confused in more detail, it does not provide information on the reasons why the model confuses them. We explore the variations in phylogenetic relatedness, sample size and image quality amongst the 56 species, along with the F1 score from the machine learning model.

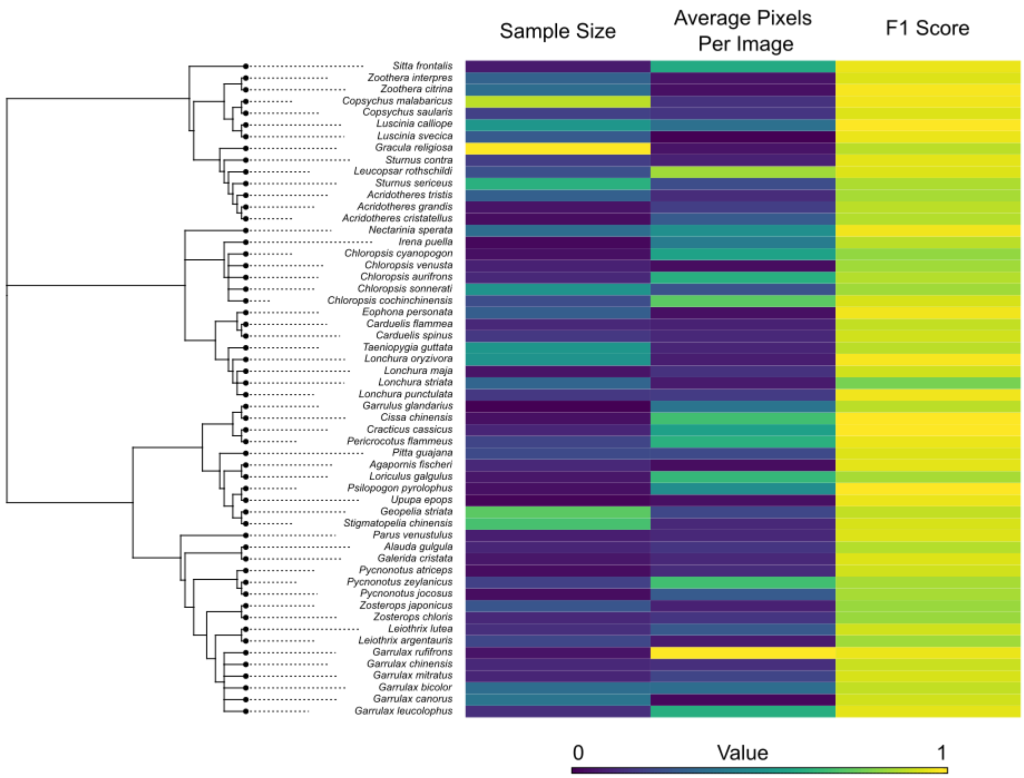

Figure 2.3: *Phylogeny of all 56 species provided in the training set, and a heatmap of the sample size, image quality and the F1 score (ranging between 0.8 to 1) from the validation data of the best-performing model. The sample size and image quality were normalized between 0 and 1; the true ranges for these are: 105917.5 to 4109047 for average pixel count per species, 71 to 239 images for the sample size. Of the variables, the F1 scores seem lower for closely related species, in certain clusters.*

The F1 score does not seem to have a linear relationship with either the sample size or the average pixel count, so we suspect class imbalance (differing sample sizes) and lower resolution images are not associated with the model performance (F1 score).

For the F1 scores, some are slightly lower between clusters of species (for instance, the leafbirds, the mynas and the bulbuls). This confirms similar trends in the confusion matrix (Figure 2.3), where species are often confused with other related species, such as the leafbird example already given.

2.4.4. Test set results

For the test set, only a subset of species was evaluated, and confusion matrices could not be generated directly; instead, we report top-1 and top-2 accuracy metrics. Evaluating the model on an independent test set highlights the generalizability of the model. The accuracy is the percentage of correctly classified images. Our model returned a top 1 accuracy of 68% and top 2 accuracy of 84%

on a test dataset constructed for 46 species (Figure 2.4). There is considerable variation amongst the 46 species for which we managed to collect enough novel data. We plot the test prediction accuracy (whether the label was correct or not), for each species, against the F1 score for the same species on the validation data. In general, the lower the F1 score during validation, the lower the test accuracies were.

These accuracies are not comparable between species since there were differences in the number of images per species. For instance, some species like the Scarlet Minivet (*Pericrocotus speciosus*) only had one image available and the model did not predict the correct label, so the accuracy for that species is 0 in our results.

Encouragingly, several species performed consistently highly, sometimes higher than the F1 score during validation (Figure 2.4). This includes some species like the Scaly-breasted Munia (*Lonchura punctulata*) and the Eurasian Jay (*Garrulus glandarius*), for which we only sourced one test-set image

This result shows that the model can be reliable, though it still makes errors, particularly for more challenging (low image quality or high visual similarity with other classes) or underrepresented (data poor) classes. The full test set results can be seen here, https://github.com/CV4EcologySchool/cv4e_cagedbird_ID/blob/main/editted_test_pred.xlsx. The filenames and cropped test images can be viewed here: https://github.com/CV4EcologySchool/cv4e_cagedbird_ID/tree/main/test_con2.

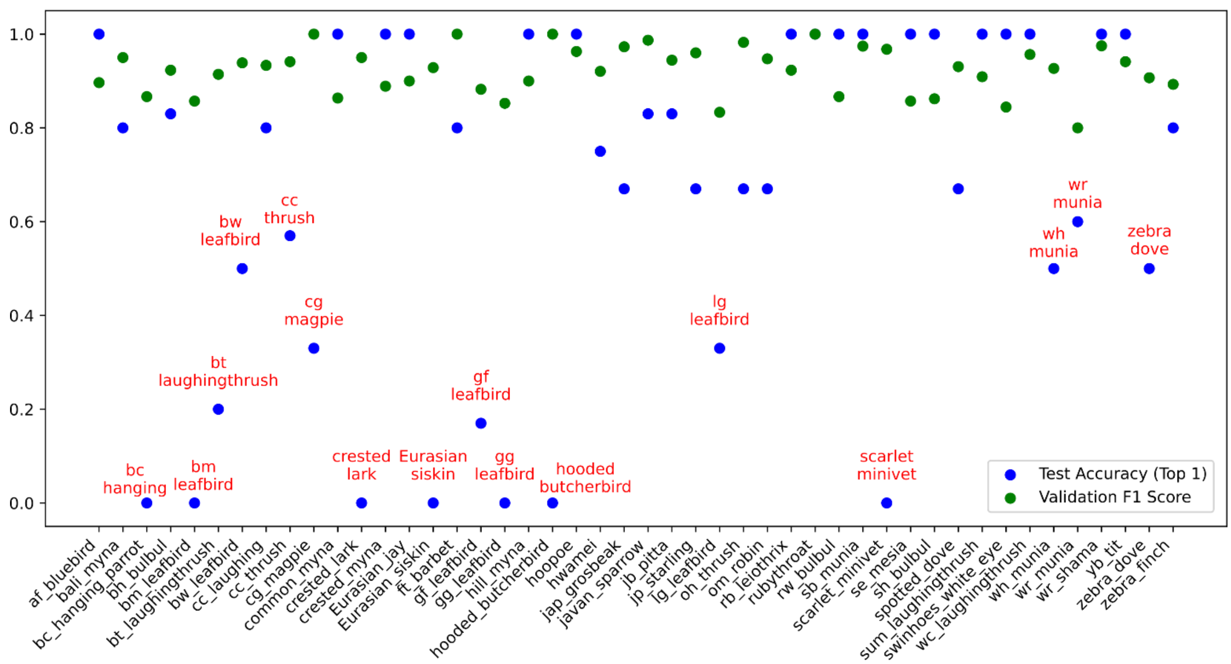

__Figure 2.4:__ Distribution of test accuracies across the 46 species of birds in the test set, with poorly performing species (accuracy <67%) highlighted in red, with the F1 score for each species on the validation data shown as a point of comparison.

To show an example of the misclassifications, the species on the left (true) were sometimes misclassified as similar looking species on the right (Figure 2.5), though the model does not necessarily struggle with rare classes (Figure 2.3, 2.4, 2.5). From these examples, regardless of relatedness, it seems that the model is relying more on the coloration or pattern of the bird (i.e. all green, black and white), to make predictions. In the absence of scale in the images, due to the cropped nature of the images, or a multimodal model that had an indication of body size (i.e. a model that is trained with images and with tabular data, like body size), it is unlikely that the model can distinguish as well between similarly colored birds (note the poor test accuracies for most of the leafbird species, Figure 2.4). At least with the case of the *Cracticus cassicus* and *Copsychus saularis*, we can see the poses and beak shape of the birds differ, though C*racticus cassicus* was incorrectly predicted on all occasions (n=4).

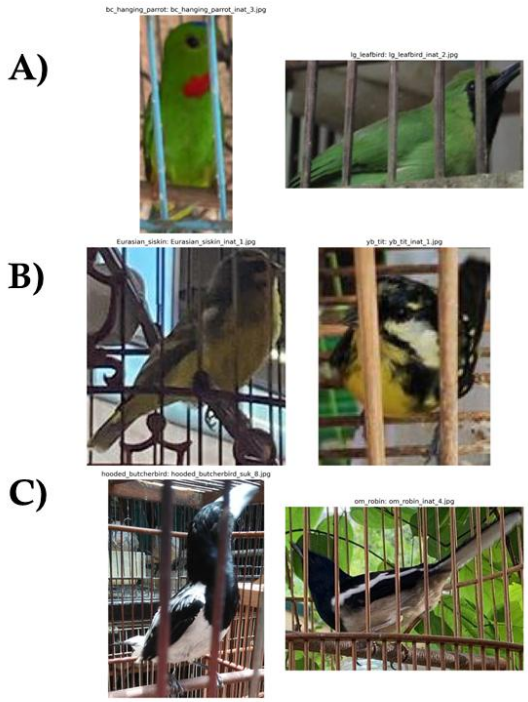

Figure 2.5: *An example of some of the misclassifications by the model on the test set. Visual similarity based on color is the potential reason the model struggled to provide the correct label (Top 1 accuracy). Image credits: Blue-crowned Hanging-parrot (Loriculus galgulus): iNaturalist user titustay; Lesser Green Leafbird (Chloropsis cyanopogon): first author; Eurasian Siskin (Spinus spinus): nathasha_pan; Yellow-bellied Tit (Pardaliparus venustulus): redpandacat; Hooded Butcherbird (Cracticus cassicus): Ganjar Cahyadi; Oriental Magpie-robin (Copsychus saularis): yvetteamplified. Further details of data collation from iNaturalist are in Table B3.*

2.5. Discussion

Our study presents a novel implementation of image-based machine learning for predicting the species identity of multiple traded live animals in physical marketplaces. The model outputs show a moderate accuracy on an independent test set of 46 species, with promising top 2 accuracy scores. This model performance score is achieved even though the images involve occlusion by cage bars and a wide range of angles, lighting conditions, and backgrounds. The model performed less well in distinguishing between closely related and visually similar bird species. Still, these are important proof of concept results that can be built on for other implementations of machine learning to identify species in highly speciose wildlife trades and potentially enhance species identification capacity amongst conservation law enforcement.

2.5.1. Model performance

Classification tasks involving closely related species (i.e. in the same genus) can be considered "fine-grained" (such as Wei et al. (2019) on terns and Xu et al. (2018) on albatrosses). Wei et al. (2019) note that bird identification is particularly challenging as there is small interclass variation (between species) and large intra-class variation, in their example regarding pose (resting, in flight) and background (the sea, the sky, grassy areas). Our problem includes clusters of closely related species with varying degrees of similarity, which is likely the most important factor driving misclassifications (Figure 2.3, Figure 2.5).

The model predicted the correct label (top 1 accuracy) for 67% on our annotated test set (Figure 2.4). While this is lower than test accuracies reported in other bird classification studies, such as 97.67% for 515 species in Adhikari et al. (2024), and 93% for 5,600 species in the Merlin app developed by the Cornell Lab of Ornithology for species globally (Team Merlin 2024), these results are not directly comparable due to substantial differences in dataset composition and evaluation condition. For example, the train-val-test splits in Adhikari et al. (2024) are not clearly described, and both Merlin and Adhikari's models are trained on much larger and more diverse datasets.

In contrast, our dataset is composed of imagery sourced from wildlife trade contexts, including birds in cages, heavily occluded individuals, and images with varying signal-to-noise ratios, all conditions that are underrepresented in existing datasets. While Merlin is trained on a wide range of image qualities, including blurry and occluded images (S. Heinrich, pers. comms, February 2025). Nonetheless, the Merlin model is trained on images of all qualities, including occluded, blurry, and distant, (S. Heinrich, pers. comms, February 2025), it does not include the specific types of imagery found in our dataset, such as dense cage bars or low-light conditions. Moreover, Merlin benefits from additional contextual inputs such as user location, which can significantly boost its accuracy by narrowing the candidate species set, for instance helping to distinguish between similar-looking species that live in different areas (S. Heinrich, pers. comms, February 2025). Therefore, while our model's accuracy is lower in absolute terms, it reflects the increased difficulty and novelty of the classification task.

In terms of the mean average precision for our model (0.85), this score is lower than other bird identification tasks, for instance Kumar et al. (2023) recorded a mAP of 0.97 on the CUBS-200-2011 dataset (a fundamental benchmark dataset of 11,788 images of 200 bird species with multimodal annotations). On the other hand, for more complex identification tasks, like fish identification using underwater cameras under variable conditions, Belcher et al. (2023) recorded a mAP of 0.67-0.95

across three genus groups. Our result means that our model works reliably for most species, achieving a good balance between precision and recall.

Though we developed a novel application of machine learning to wildlife trade data, existing and larger-scale tools like Merlin and Google Lens can identify birds from caged images. Further, from a sample of four of our test images (Figures B7-10), Merlin could identify all but one correctly. However, both Merlin and Google Lens models were unable to identify certain species such as the blue-tinged Common Green Magpie (*Cissa thalassina*), which differs from its wild counterparts that are a more vibrant green, as it generally has a lack of lutein in its diet in captivity. Though these tools are not necessarily field or context ready, their vast databases can be made use of to assist with field identification and training. Yet, these tools do not provide accuracy levels per species and other practical information that law enforcement users may require (like the protection status). As such, training on trade-specific data is still valuable as there are various changes to the bird's appearance that are not observed in healthy, wild individuals. Nonetheless, we can view our findings relative to Merlin as the state-of-the-art baseline for identifying birds.

Other studies have looked at the accuracy of free automated applications for plant identification (Hart et al. 2023), finding that generic photographic identification applications like Google Lens had the poorest accuracy amongst other dedicated species identification apps, though it performed better on cropped images that showcased the key parts of plants. Our method still holds relevance for many other wildlife trades that are obscure (i.e. not enough images on Google to be included in Google Lens), nor as well studied as birds (for instance detailed applications like Merlin do not exist for every traded taxa).

Regarding the broader issue of occlusion in our images, Tan et al. (2022), using camera trap data, found that their model (object detection combined with classification) did not correctly identify images where animals were occluded (for instance by vegetation). Thus, training a model on a highly occluded dataset like ours may imply that the accuracies are lower than unoccluded objects, but the model can still make correct predictions. Though we tested several different augmentation methods (Table B2), only horizontal flipping markedly improved the model performance (see CometML experiments). When selecting augmentations, we selected what we thought was appropriate given our domain-specific knowledge, such as intensity- and occlusion-based augmentations. However, no occlusion-based augmentations improved model performance.

Schneider et al. (2020), in a study on camera trap images for 55 species (mammals, birds and others) in Canadian national parks found that, particularly for imbalanced datasets, species with fewer training images available (<500) yield variable but poor recall scores. We did not have 500 images available for any species included in our dataset (Figure B2), so Adhikari et al.'s (2024) minimum of 136 images per species may be more reasonable for future projects. Nonetheless, others have reported high accuracy with datasets of limited sizes (e.g. Hernández-Serna and Jiménez-Segura (2014) with 11,000 training images). However these examples utilised other CNN architectures and were trained on different taxa, so they are not comparable to our use of ResNet-18 on images of caged birds.

2.5.2. Phylogenetic and morphological confusion

In terms of the model performance on the validation data, there were no obvious patterns between relatedness, image quality, and class sample size (Figure 2.3). It is possible that other factors affect model performance. For the Merlin bird identification application (which includes 6,900 bird species), birds that are more distinct are easier for the model to identify (i.e. unique features like crests or bright and rare colors) compared to birds with few distinguishing characteristics (Team Merlin 2024). Our dataset includes several individuals with large areas of black (e.g. mynas) or green (white-eyes, leafbirds etc.) colouration, and the extent of these patterns may affect classification results (Figure 2.5). Xu et al. (2018) and Wei et al. (2019) all point out that the most salient features for machine learning models to distinguish between highly similar categories of birds are the colour, shape, and pattern.

2.5.3. Can AI models be used to classify animals sold in the wildlife trade?

There have been studies that can detect the presence of exotic pet sales from images (Kulkarni and Di Minin 2023) or the presence of a target group (pangolins) across different anthropocentric contexts (Cardoso et al. 2023), though image-based multi-class applications have been scarce. As highlighted earlier, there is one recent innovation that has demonstrated success with multiclass tasks using wildlife trade data, the FinFinder app, with a moderate sample size of 15,000 images and a considerable number of species (35) (ConservationXLabs 2022). The image quality in their training and testing set is unknown. Still, it may be easier to build tools that can identify byproducts, animal parts or whole dead organisms that can be photographed clearly and do not move.

Our model only predicted the correct species for 67% of test images, although the correct species was found in the top two results on 84% of images. While it is unclear where the threshold might be for utility in a marketplace enforcement context, the model is clearly not deployment-ready for use without careful integration of limitations. The model could be used as an initial guide, if users are aware of those taxa that are most commonly confused in the output. Subsequent research in this project showed that law enforcement are already using generic tools such as Google Lens (Fiennes et al. in review) In practice, models like these could be used by law enforcement to assist with species identification in real time, for instance, through the use of a handheld mobile app as birds are encountered in marketplaces or seizures.

This shows that we should value taxonomists and their expertise, even if they might be theoretically slower than AI-produced results. Campos et al. (2024) argue that assuming automated classifications possess equal accuracy and value as those by taxonomists challenges the credibility of taxonomic work. Further, there are considerable ethical considerations when implementing image-based technologies in the field, that relate to privacy (Simlai and Sandbrook 2021), risk of incrimination to human individuals participating in the trade (Duffy 2022:142) and environmental concerns from the energy and water costs used to host and run AI models, though ML has lower material needs than generative AI (Simlai and Sandbrook 2021).

2.5.4.Future model development

2.5.4.1. Changes to data collection

Future research can hopefully improve on our results. Firstly, we would suggest training on more data and a second training on crops of the crops (which are inherently lower image quality, and which target particular sections of the bird); second, we would leverage masking augmentations that would mimic large occlusions like the cages. Though Merlin has a similar data inclusion threshold to us (S. Heinrich, pers. comms, February 2025), they have, in general, better-quality images submitted by experienced birders on digital cameras, so there may be trade-offs between image quality and dataset size. It is possible that low quality, small datasets are simply not able to be predicted with high accuracy by image-based models alone. However, Merlin's geofiltering approach may apply to the context of identifying caged birds, though birds from all over Indonesia are found on Java, so location of sale rather than supply is less useful.

2.5.4.2. Vision-language joint embedding models

As mentioned, our problem includes clusters of closely related species with varying degrees of visual similarity - which poses the question, how well did our classifier do for visibly similar birds after clustering their embeddings (numerical representations of data)? It is most likely that visual-semantic embedding would improve the generalizability of our model; using text (i.e. from a knowledge base) allows the model to generalize better to variations as it learns broader semantic connections (Xu et al. 2018), in addition to visual information. Xu et al. (2018) used Wikipedia as a knowledge base in addition to images of birds from the CUBS-200-2011 dataset. In the context of Indonesian bird identifications, there are recent field guides (Eaton et al. 2021), which have rich text descriptions that could be coupled to labelled images.

2.5.4.3. Data sharing

Ultimately, this research serves as a call, where possible given security concerns, to develop a free open-source repository of images for studies of this nature, as well as code-sharing. This would allow our results to be improved and help make the design and implementation of technology more accessible, bearing in mind the ethical concerns of AI. In other areas like forest monitoring (e.g. for species identification and forest biomass assessments) there has been progress in ensuring data is open-access, such as the OpenForest project (Ouaknine et al. 2024).

2.5.5. Conclusion

Our results represent a benchmark performance for machine learning models on multiclass data from the caged bird trade (67% on unseen data). This is an important baseline for people to draw from for bird trade in other geographies or other wildlife traded in highly occluded contexts. Our approach has shown how to build and test a model in a practical, real-world scenario. Training on low quality images may never achieve particularly high accuracy, but it remains to be seen if this is better than both non-expert human baselines.

Nonetheless, our tool shows promise as part of a human-in-the-loop system, in which local taxonomists and birders could verify model predictions and retrain the model with these correct data (Xin et al. 2018). With a top-2 accuracy of at least 80%, the need for manual identifications could be significantly reduced for market surveys or patrols. Whilst our approach is designed to assist law enforcement professionals, it cannot replace experienced taxonomists (who can likely identify close to 100%).

Citizen science efforts to survey national parks in Bali (Squires 2023), show that there is a growing and capable set of birders in Indonesia. If results from AI cannot be improved, the resources and attention could instead be spent on building a critical mass of taxonomists to assist with improving species identification capacity amongst groups like conservation law enforcement. Still, further research is also needed to understand the social worlds, roles and design needs of conservation law enforcement who are the hypothesized users of these tools and consider if they are really needed.

With the potential to transform wildlife marketplace monitoring through training of image recognition tools, machine learning has the capacity to greatly enhance species identification in the field. However, as this research shows, accurate classification based on visual information alone is insufficient. Still, further research is also needed to understand the social worlds, roles and design needs of conservation law enforcement who are the hypothesized users of these tools and consider if they are really needed.

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Here we go! – early technology musings

By looking at technology as an abstract concept, I started considering technology more broadly, so the accuracy of the models is acceptable; it might work. But, as we move into the age of artificial intelligence, the role of conservation technology needs to be carefully considered. How could it be made accessible to the people that need it? How could it be co-designed? Could it increase the surveillance and punishment of traders? There are still so many unknowns to me; what does the day-to-day of conservation law enforcement look like? What are the main barriers they face in their work, and why has the bird trade become characterised by poor, weak, corrupt and lax law enforcement?

The development of the chapter just gone was greatly advanced by my attendance at the Computer Vision for Ecology Summer School at the California Institute of Technology (Caltech), in an amazing few weeks spent in Los Angeles in the summer of 2023. This research was in part funded by the Resnick Sustainability Institute at Caltech. Whilst it is a generous contribution, and the funding of sustainability research can be murky, I'd like to address my more recent finding that the Resnick family, who have made their fortune off farming pistachios, has led them to use and maintain a greater monopoly in California's water reserves than any other private counterpart. The Resnick family has also donated millions of dollars to the Israeli Defence Forces over the last few years[1]*. If I had known about the Resnick's water hoarding or contributions to a genocide, I might have never attended this training course. As a staunch defender of the Free Palestine movement, I can't commit to decolonial research and not acknowledge the illegal occupation of Palestinian land by Israel and the irony of universities accepting money from polluters to fund sustainability research. Further, the more I learn about AI, the less I want anything to do with it. I was initially impressed by these models, like ChatGPT and CoPilot, and I've used them for various purposes in research. I was horrified to discover how these models directly accelerate climate change through exorbitant water use in already arid environments (like Mexico, where data centres are), using around half a litre to write a 100-word email*[2]*. As I write this thesis, many people have died, including potentially thousands of wildlife and pets, as fires burn in the very same region as Caltech, Pasadena. It's hard to see how AI use won't accelerate water scarcity and drought.*

Despite the dystopic anxieties around AI, I've relied on tools like Chat GPT and CoPilot for code debugging and queries. I can't manage a good day's work without the structure of the to-do list app, the Headspace app or my new friend, FocusPomo.

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[1] Levine, 'California Pistachio Billionaires Funding Israel's Occupation Regime'.
[2] Thier, 'California Wildfires Raise Alarm on Water-Guzzling AI like ChatGPT'.

Chapter 3. Species identification and law enforcement praxis during the governance of (il)legal songbird trade

3.1. Abstract

Illegal wildlife trade (IWT) can be considered a "wicked problem", where complex social, political, and economic factors interact with different stakeholder groups to produce barriers to biodiversity conservation. The songbird trade in Indonesia is a global IWT hotspot where law enforcement is further complicated by the complexity of the megadiverse songbird communities that are traded. Conservation law enforcement is often oversimplified as a policing function based on punitive and financial penalties for infringement of rules. A better understanding of the role of the range of complex challenges in IWT policing could facilitate more effective action to manage the trade.

Here, we explore the experiences of law enforcement officers – a group within IWT that has been neglected by researchers – who are responsible for enforcing laws around the songbird trade, and the challenges that they face. Through interviews and focus groups with various law enforcement agencies and personnel across Indonesia, we describe law enforcement praxis within this trading system, highlighting the enablers and barriers of their work. Through these discussions, we aim to provide a holistic and nuanced overview of how law enforcement officers think and act within both formal and informal systems of regulation that might offer diverse opportunities to improve outcomes for birds, traders, and officials.

The key findings are that law enforcement preferentially takes a highly social, informal approach to working with illegal traders rather than adopting the punitive or heavy-handed method demanded by formal regulations. We report a general lack of taxonomic confidence amongst law enforcement, while exact species identification is sometimes a prerequisite for action. Enforcement tends to occur away from marketplaces but in diverse locations along the trade chain from forest to customer homes and involves covert observations and operations to gather intelligence.

Based on the insights provided by our participants, we recommend more formal training in species identification along with exploration of co-designed taxonomic aids, and evaluation and greater study of the informal "socialisasi" approach to governance compared against more punitive approaches. Such formalisation of informal taxonomic knowledge, and informalisation of enforcement, may enhance the management of other wildlife trades.

3.2. Introduction

Issues or conflicts in conservation are often termed ‘wicked problems’. A wicked problem is complex and ambiguous; the solutions are not easily defined and have no clear boundaries or end point, and different stakeholders or actors may have conflicting interests, values and definitions of success (Rittel and Webber 1973). A prime example is legal and illegal wildlife trades (IWT), both multibillion-dollar industries spanning thousands of species (Phelps et al. 2016). IWT includes the trade of endangered, protected, and quota-regulated species (Wyatt 2009). IWT constitutes a wicked problem as it is difficult to define due to its diversity of species, scales, and geographies (Thomas-Walters et al. 2020; Arroyave et al. 2023). Responses range from militarized patrols and legal enforcement to demand reduction (Öckerman et al. 2024). It intersects with extinction risks (Hinsley et al. 2023), welfare (Wyatt et al. 2022), cultural inequalities (Liew et al. 2021), labour standards (Simlai et al. 2023), and human rights (Osorio and Bernaz 2024). These overlapping concerns make IWT a problem that can only be managed, not solved.

Wildlife trades, especially those involving many similar-looking species, often fall into legal ‘grey’ areas, or remain unregulated and understudied (Roberts and Hinsley 2020). This greyness poses a significant challenge for conservation practitioners, as these trades can put immense pressure on wild populations. Greyness challenges also apply to the enforcement of regulations by conservation law enforcement (CLE), defined by Massé (2020) as ‘the organised practices, as well as the authorities, used to enforce laws and norms related to the use of biodiversity and the regulation of activities within conservation spaces’; and includes both police and customs officials working on wildlife crime (Dickinson 2022).

IWT is often framed as a crime since certain activities make it unlawful (Duffy 2022, p.31). Yet IWT is wrapped up in preexisting economic and social practices. A change of law, not a change of practice, often creates an 'illegal' wildlife trade, and these intricacies are central to what makes IWT a wicked problem. Particularly complex IWTs may also be considered mundane and everyday (Duffy 2022, p.35), though may still experience social legitimacy (t’Sas-Rolfes et al. 2019). Trades that are not perceived as illegal by local actors have been termed ‘contested illegalities’ (Hübschle and Margulies 2024).

A fundamental yet underexplored issue in the wicked problem of IWT is the role of species identification, which can be considered an important bottleneck to preventing IWT. When IWTs are highly speciose or involve indistinguishable species, species can be misidentified or unidentified, impacting the accurate estimation of viable harvest levels and detection of illicit trade (Alfino and Roberts 2019). Species identification may be a precondition for action; if taxonomic expertise is lacking, law enforcement may be weakened through delays or errors. Accurate identification is difficult, especially for similar species or processed products (Svolkinas et al. 2020). The bulk of this identification labour falls on CLE, though they often lack the taxonomic expertise needed (Gouda et al. 2020).

While taxonomy is in theory a "tame" problem (Rittel and Webber 1973) that has a set of rigorous, objective rules by which species can be identified, the reality is more complex. There are several examples of this across wild resource use, take fisher communities that have greater knowledge of Brazilian shark species than the officials who are tasked with monitoring the fishery (Filho et al. 2021). Western, binomial systems of taxonomy may be superseded by folk taxonomy based on traits like colour or song, for instance, in the Indonesian songbird trade (Iskandar et al. 2021). In multilingual regions, species names and knowledge systems multiply (Otieno et al. 2015), adding further complexity. Uncertainty over species identity affects legal status and enforcement, reshaping the wicked problem in turn. The question is not whether better species identification will 'work', but rather what impact it will have. This research explores how CLE navigates taxonomic uncertainty in practice. Building on Massé's concept of 'police power in green' (Massé 2022), the understanding that conservation efforts increasingly rely on police power to combat illegal wildlife trade, and critiques of enforcement-first approaches (Duffy and Massé 2023), we examine how enforcement operates on the ground—formally, informally, or not at all.

3.2.1. Songbird trade in Indonesia as a social, cultural and environmental issue

Species identification and subsequent enforcement is a challenge across many IWTs (Alfino and Roberts 2019; Marshall et al. 2021). Here, we explore these challenges through the case study of the Indonesian songbird trade and those tasked with identifying it, such as conservation law enforcement. In Indonesia, the trapping and trading of birds is primarily driven by the demand for pets within a largely domestic market (Indraswari et al. 2020). Most notably, on the island of Java, there are deep-rooted traditions of keeping birds at home derived from royal nobility (Pradita and Wardhana 2021). The trade has various structural inequalities, associated with race and social class (the rich collecting birds and the poor hunting under economic pressure). These multiple actors, processes, and viewpoints necessitate treating songbird IWT as a wicked problem.

Since the 1990s, there have been rising demands for a range of species for singing competitions (Indraswari et al. 2020), which has led to region-wide declines in several bird species (Eaton et al. 2015). Due to high levels of wild harvest to meet the demand for birds, conservationists have termed this trade “the Asian Songbird Crisis” (Sykes 2017). Rather than a singular crisis, there is a complex pattern of rolling local declines (Eaton et al. 2015) and dynamic trends that increasingly cast the net wider across Indonesia’s native birds (Fiennes et al. 2024). Trade has become megadiverse, with protected and rare species often openly displayed in marketplaces, with the blame often directed at lax, corrupt or unconcerned law enforcement (Maulany et al. 2021; Shepherd and Leupen 2021).

Enforcement is complicated by legal ambiguities and practical challenges in species identification. Indonesia’s conservation law (P106) and a 2019 regulation on animal transport provide two legal pathways for prosecution (Guciano et al. 2024, p.9). Violators can be charged under this law if these species are trapped, transported en-route (e.g. to marketplaces), traded in person or online, or possessed at home. Another law (established in 2019) requires that all animals, including captive-bred or non-native animals, be accompanied by a permit for any inter-provincial level or higher travel with a health certificate. Unprotected species are regulated through a system where annual quotas for harvest and trade are set by the Indonesian National Research and Innovation Agency (BRIN) and published by the Ministry of Environment and Forestry, though how these are enforced is unclear.

Here, we explore how improvements in species identification capacity could aid CLE in tackling wild bird trafficking within this legal context (Guciano et al. 2024, p.4). Identification challenges likely occur at all stages of the trade chain in complex, rich and noisy environments where taxonomic skills can be stretched to their limits. For example, members of conservation agencies who monitor trade in marketplaces may have scant views of injured or artificially sprayed birds in (deliberately) covered cages or rely on the call of a protected species in a crowded and noisy environment, which is a more complex task than visual species identification. Some studies across Indonesian marketplaces (e.g. Rentschlar et al., 2018) have shown that up to 33% of the volume of birds cannot be identified to species level in some market surveys, mostly amongst genera that experience high rates of cryptic diversity, such as white-eyes (genus Zosterops), a whole host of small green birds with white eye rings sold in bird trade across Asia (Martins et al. 2020). Other wider issues include the number and capacity of law enforcement officers, facilities used by law enforcement officers and community awareness (Maulany et al. 2021), and we need to understand how such issues could complicate species identification.

By centering the lived experiences of CLE officers, this study reveals how taxonomic uncertainty shapes enforcement outcomes in the illegal songbird trade in Indonesia, focusing on urban environments at the demand end. We argue that species identification is not merely a technical challenge but a critical site where conservation, enforcement, and local knowledge intersect. In doing so, we highlight overlooked barriers to effective conservation and identify opportunities for capacity-building that move beyond enforcement-first paradigms. This research contributes to a more grounded understanding of CLE praxis and opens space for more nuanced, context-sensitive approaches to tackling IWT as a wicked problem.

3.3. Methods

Before we outline our methodology, we seek to establish our positionality from the first author's perspective. I (SF) am a white researcher, disciplined originally in conservation biology and from a relatively middle-class background in the UK. Though I learned Indonesian for around a year before embarking on fieldwork, I relied heavily on academic and field collaborators. Thus, the geography of this study was determined by access and fieldwork constraints (Dickinson 2022). Anything we present here is a partial reflection of the Indonesian songbird enforcement landscape and is through the lens of CLE engaged in top-down governance (Arroyave et al. 2023) and entrenched with relatively high levels of state power (Mason et al. 2018).

We sought to understand how CLE views and socially constructs songbird IWT as an issue. We selected the relatively open form of focus group discussions (FGDs) to discuss sensitive matters around law enforcement praxis (Newing 2010, p.54). Though there are risks of dominant individuals shaping debates or members of a group thinking similarly (Nyumba et al. 2018), we hoped that bringing multiple agencies together would introduce sufficient variation to capture the nuance of law enforcement's lived experience. Group discussions also allow participants to construct shared understandings by reflecting on similarities and differences in experience and stimulating one another's thoughts. We began each session with a short introduction and project presentation, which allowed us to remind participants of the project's aims. Following the introduction, we used a sensory elicitation exercise to situate participants in the sensory environment of the marketplace. Next, we conducted focus groups to ask law enforcement about their job in general, the different enforcement activities that they are engaged in, the social contexts of enforcing trade and the role of songbird identification.

3.3.1. Sensory elicitation

Species identification focuses on senses and sensing. Inspired by Lyon's (2016) use of audio-visual montage of stills interspersed with audio recordings to conduct a rhythm analysis of the Billingsgate Fish Market in London, we use audiovisual montage to recreate or resurrect the sensory environment of a bird marketplace in the meeting room and constitute a ‘rhythmic production of space’ (Lyon 2016). In line with the subfield of sensory ethnography, these montages use the lived environment as the object of sensory elicitation with participants (Pink et al. 2010). We used binaural microphones, which allow the listener to hear rich sounds at varying degrees of closeness, to record the spatial elements of sound at wildlife marketplaces (Coyne et al. 2006). Each participant was shown a one-minute immersive sensory experience before the focus groups to set the scene. This ‘experience’ consisted of a montage of videos of different birds in a Jakarta bird marketplace overlaid with binaural recordings, using noise-cancelling headphones. Ideally, we would have shadowed CLEOs whilst they were working, using a walking ethnography (Pink et al. 2010) to understand their lived experience more closely, though for ethical and access reasons we were unable to shadow CLEOs.

3.3.2. Focus group discussions

Next, we used focus groups to understand law enforcement's everyday working experiences. We tested exercises for use in focus groups directly and adjusted them iteratively in the next focus group. Data were collected from verbal and written answers from participants to largely open questions. Questions focused on enablers and barriers of their general praxis, the process of songbird identification, and where this fits into their everyday work and lived experience of enforcing songbird IWT. We asked law enforcement about species identification by discussing a range of popular species with them. We constructed a list of 10 species based on the most seized species by volume from Indraswari et al.'s (2020), and others of known popularity in singing competitions and ownership. We used laminated visual aids to stimulate discussions and explore taxonomic ability informally within groups of participants. We also included more than one example of popular genera known to include look-alikes (for instance, the leafbirds (*Chloropsis*) and the white-eyes (*Zosterops)*) (all species can be seen in Figure D1).

3.3.3. Locations of data collection

Data collection took place in cities within Java (Jakarta, Bandung, Yogyakarta, and Surabaya) and West Kalimantan (Pontianak), renowned for their role in the bird trade (Chng et al. 2015; Rentschlar et al. 2018). Although Pontianak is not the largest urban market outside Java, recent research indicates it is an emerging bird source, with trade levels comparable to neighbouring islands (Rentschlar et al. 2018).

3.3.4. Participant recruitment and consent

We worked with four agencies involved in CLE. Following the classification of Arroyave et al. (2023) we define agencies responsible for nature conservation (Balai Konservasi Sumber Daya Alam (BKSDA) and animal quarantine (Agricultural Quarantine (BKP), referred to henceforth as Quarantine) as environmental authorities, and wildlife law enforcement bodies such as GAKKUM (a portmanteau on PeneGAK huKUM, the Indonesian phrase for law enforcement; the Law Enforcement Division of the Ministry of Environment and Forestry) and the local and regional police (POLRES) as control authorities. Control authorities have the legal authority to perform direct enforcement activities and enact conservation law enforcement practices (Massé 2020). The conservation law is largely within BKSDA's remit and is enforced by GAKKUM from within the same ministry (Environment and Forestry). The regional police also identify songbird IWT in their work and provide additional capacity for enforcement. At times, it needed to be clarified which of the four agencies was responsible for songbird IWT, given that there are two pathways (quarantine and conservation law) through which songbird IWT can be legally enforced.

For comparative purposes, we aimed to conduct one FGD in each major consumer hotspot for bird trade across provinces in Java and Kalimantan. From the four government agencies across five focus groups, there were 57 participants in total, ranging between 8 and 13 per discussion. Participants were recruited by sending terms of reference and invitation letters to the head of each agency through our local collaborators, Yayasan Kausa Resiliensi. Participants were not randomly sampled since the selection was at the agency head’s discretion, though we aimed to have equal participation across the four agencies in each workshop. Before the study commenced, we asked individuals for free, prior, and informed consent (FPIC). All participants were remunerated for their time with the per diem fee for government employees.

3.3.5. Triangulation

Where necessary, we used field notes, participant observation in marketplaces, and one-to-one semi-structured interviews with academics and practitioners later in the field season to triangulate the data from our law enforcement participants. Interviewees were compensated with a standard hourly rate and were also asked for their FPIC. This data helped to supplement any gaps in understanding songbird trade governance. From January to May 2023, we visited nine bird marketplaces across each of the research locations, observing their architecture, trader-buyer dynamics, and bird welfare. Visits lasted about two hours, with each marketplace visited at least twice, except for Jatinegara in Jakarta which was visited once. In May and June 2023, we conducted sixteen semi-structured interviews (eight in person, eight online) with experts from conservation organisations and universities about species identification, extinction and crime relating to bird trade.

3.3.6. Data analysis

The qualitative data from FGDs and interviews were analysed using NVivo 11 qualitative software to organise the emerging codes and reflexive and analytical thinking processes (e.g., memo writing and a record of field notes) (Aujla 2020). Direct quotes are *italicised,* followed by the participant code*,* whereas paraphrased quotes are written in normal text. Participant codes for CLE use the abbreviations BKSDA, GAKK, KAR, and POL followed by a number, e.g., “BKSDA_2”; "X" is used if the participant could not be identified. Academic (ACA) and NGO (NGO) codes are based on location, e.g., “ACA_OUT_1” for outside and “ACA_IND_2” for inside Indonesia. Subsequently, we performed a thematic analysis, using inductive coding (Newing 2010, p.6) to explore emerging perspectives around bird extinction, sustainable trade, and their combined consequences. While grounded theory principles guided the study, the analysis was also informed by prior reading (for instance on species identification) and theoretical insights (for instance. Focus groups were conducted in Indonesian, recorded and transcribed by field collaborators and later translated (script in Appendix C). Interviews were primarily conducted in English and later transcribed (script in Appendix C). We received approval from the University of Leeds research ethics committee (AREA FREC 2023-0419-521) and fieldwork was conducted under a research permit (311/SIP/IV/FR/11/2022) from Indonesia's National Research and Innovation Agency.

3.4. Results

Here, we describe the role of law enforcement in managing IWT, who the people involved are, and what the laws are. Secondly, we outline how songbird IWT is identified, detected, and enforced and where species identification fits in broader Indonesian law enforcement praxis. We also discuss any challenges that affect their work, including identification of species.

3.4.1. Agency roles and governance structures

The frontline in songbird IWT monitoring and detection is BKSDA and Quarantine, the environmental authorities. BKSDA saw their role as '*preventative rather than punitive*' (BKSDA_7), in a conservation role in anticipating the extinction of rare and threatened species through trade. Quarantine viewed their '*role as preventing disease entry and exit and monitoring the wildlife trade, including rare and endangered species'* (KAR_3). Who does enforcement and is accountable was sometimes unclear. For instance, Quarantine discussed their lack of '*authority in bird markets, and [that they] need better tools to help them in their role'* (KAR_3) and that they '*focus more on health and [illegal wildlife trade is] not our task'* (KAR_4) and so they may feel coopted into including IWT issues in their remit. Still, in November 2019, Indonesia's quarantine law was updated to give more power to Quarantine to regulate domestic wildlife trade (Guciano et al. 2024, p.9). Earlier, in 2016, '*the authority of BKSDA [was] reduced and taken over by the Law Enforcement Agency [Gakkum]'* (BKSDA_4).

3.4.2. Law enforcement activities

3.4.2.1. Where does identification need to happen?

Multiple agencies reported being tasked with songbird IWT, so there is evidence for sustained political will. In the direct context, activities include patrolling known trade locations, conducting confiscations, and intercepting shipments of unlawful birds. Indirectly, CLE (mostly BKSDA) uses surveillance (intelligence gathering through reports (BKSDA_4), persuasion (BKSDA_6), socialisation (POL_5), patrols, and sharing information with other agencies and stakeholders.

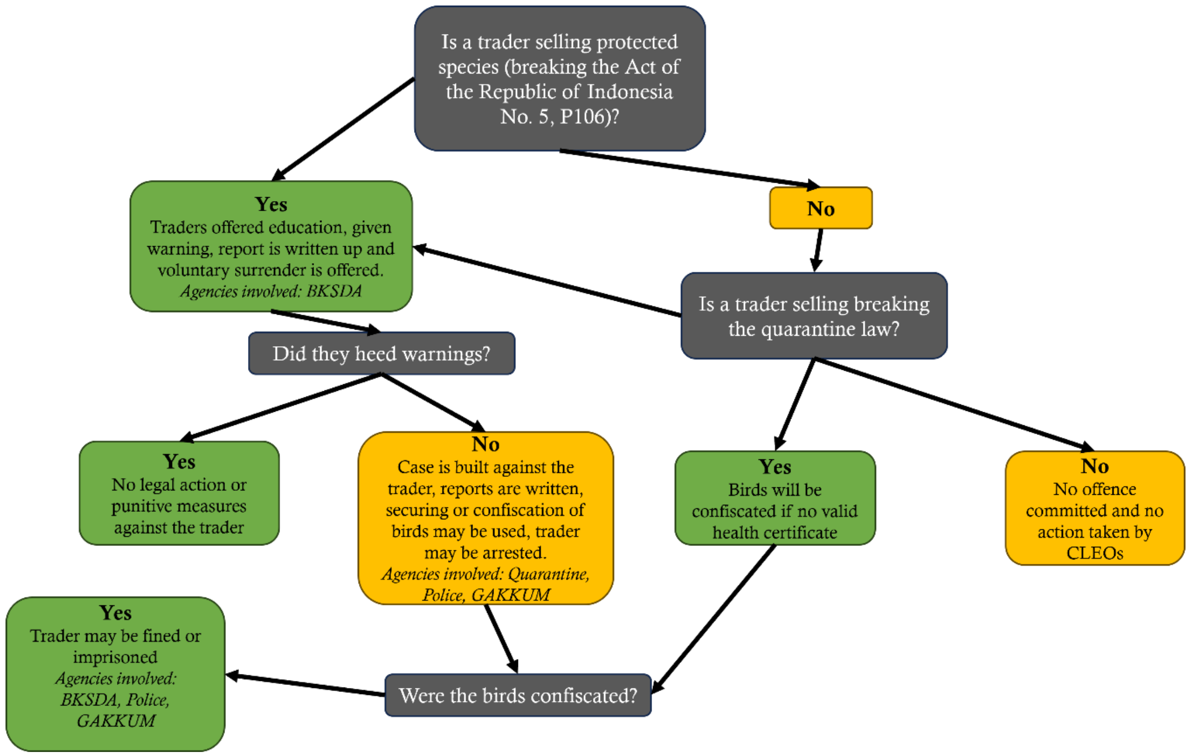

Figure 3.1: *A process diagram showing the detection of illegal songbird trade by environmental and control authorities at a marketplace in Indonesia and the subsequent judicial pathway. One trader is suspected of selling protected species under the Conservation of Biological Natural Resources and Their Ecosystems Law.*

No further action is taken if a seller is not found selling protected species (BKSDA_11) (Figure 3.1). If a trader is selling one or more protected species (that law enforcement can determine), the trader is first informed that they are selling protected species (which the trader may or may not know (BKSDA_22)) or they might '*pretend they don't know*' (GAKK_4). During this process, they need to "*engage skillfully*" (BKSDA_6) with traders in socialisation practices. An incident report will be created internally in BKSDA (BKSDA_9). Then the trader will be issued a warning and may be asked to surrender the birds (BKSDA_4) voluntarily. If they are found to not have heeded warnings on later occasions, BKSDA could cooperate with either the police or Gakkum to open a case and conduct an investigation (BKSDA_4). The trader might still be offered the opportunity to surrender the birds; if not, they face the possibility of confiscation and arrest (GAKK_4). Confiscations offer agencies opportunities to remove species suspected of being protected and then identify them later to the species level (BKSDA_5). Confiscations (or seizures) rely on inter-agency collaboration; for instance, Gakkum does not have jurisdiction to search people's houses, but the police do (GAKK_16). If a case of songbird trade is prosecuted, '*the trial has two witnesses: legal and regulation experts and identification witnesses (from the BKSDA or Conservation Agency officers). If a case of species is misidentified in the trial, it can be contested by the opposing lawyer*' (BKSDA_5). If the trader is not released, they may be sentenced to a fine or jail time, though maximum penalties are rarely invoked (Adhiasto et al. 2023)

A similar process to Figure 3.1 would be followed if the Quarantine law is violated, '*if there are (protected) animals without documents, they will be handed over to the authorities'* (KAR_10). However, a less investigative approach is deployed in this legal pathway since species identification is not a requirement. This approach would also most likely target intermediaries in the trade chain, such as smugglers, couriers or more high-profile middlemen. Quarantine CLEOs can confiscate if a shipment seems suspicious then identify the species later (KAR_4).

Participants highlighted a range of locations along the trade chain where songbird identification needs to happen, often focusing on somewhere other than the marketplace. These locations were ports (n=4), post offices (n=1), international border posts (n=1) and airports (n=1). Only one participant explicitly mentioned *'in the bird market'* (GAKK_8). Investigations into online trade are likely more complex: *'many people do live streaming [to sell wildlife on TikTok or Instagram]. However, it's difficult…we must establish trust so they [are] willing to make a transaction and meet up'* (POL_3).

3.4.2.2. How do CLE currently identify birds?

There were no standardised practices for identifying birds in the field. Instead, a range of manual and online, technical tools are used. In particular, we discussed the methods used for identification, identification skills and taxonomic knowledge of CLEOs, these are summarised in Table 3.1.

Table 3.1: *Bird identification methods and performance used by conservation law enforcement officers, summarised across agencies and locations.*

Method	Description	Mentions	Strengths	Limitations
Printed & Photo Guides	Includes A Field Guide to the Birds of Borneo, Sumatra, Java, and Bali (MacKinnon & Phillips, 1993) and A Portrait of the Illegal Wildlife Trade in Indonesia (Ministry of Environment, 2017)	14+	Trusted,visual references	Heavy, incomplete, limited angles/species, not bird-specific
Expert Consultation	Asking colleagues (e.g. BKSDA, Gakkum) or	9	Access to experienced identifiers	Informal, dependent on

	hobbyists via WhatsApp			availability and network
Google/Web Search	General online search for species ID	12	Easily accessible	Inaccurate, lacks detail, hard to search without prior knowledge
Google Lens	AI-based image recognition via smartphone camera	5	Quick, tech-enabled	Inaccurate, limited database, some species undetectable
Burungnesia App	Digital bird guide specific to Indonesia	1	Localized tool	Limited mention, unclear effectiveness

3.4.2.3. How do they perform identification tasks?

For the informal species identification test (Figure D1), which explored CLEO bird identification skills, only 30-40% of the 10 most seized species were identified at the species level by members of law enforcement. Some species were unable to be identified at the species level, such as the Bar-winged Prinia (*Prinia familiaris*). However, the family's common name (Prenjak) was mentioned in one workshop in Bandung. In no workshops were the white-eyes identified to the species level. Certain species, like the Zebra Dove (*Geopelia striata*) and the Oriental-magpie Robin (*Copsychus saularis*) were always correctly identified. Some CLEOs were familiar with the Greater Green Leafbird (*Chloropsis* sonnerati) at the species level; others referred to the common name for the leafbird genus '*cucak ijo'*, which could have been any of the three species included in the exercises.

3.4.3. Barriers to effective songbird trade governance

Even with the clear benefits of collaboration, a range of legal pathways to detect and prosecute songbird IWT, and several songbird identification methods available to CLE, there are various barriers to successful law enforcement. We identified four categories of barriers (Table 3.2) that prevent CLE from enforcing laws regarding songbird IWT. Firstly, legal barriers relate to problems with the existing regulations that govern CLE. Several participants mentioned that there were simply too many species listed in the conservation law. Secondly, cultural barriers involve norms, relationships, and social processes and can be viewed as 'people problems' at individual or organisational levels. Mention of 'people problems' like corruption was rare, though one CLEO mentioned being offered to 'cut the certificate' by a trader: *'A Bali Myna with a certificate costs Rp. 3,500,000, while without a certificate, costs Rp. 2,500,000. Perhaps the traders allow it because I am a police officer'* (POL_2). There was sympathy amongst CLEOs over the risks of law enforcement impacting the livelihoods of traders; for instance, '*[bird trade] is a dilemma because many people rely on it for their livelihood'* (KAR_10) and that '*those who have money can buy, but those who don't have money will hunt'* (BKSDA_4). Third, technical barriers relate to practical, on-the-ground issues, like staff shortages or a lack of necessary equipment. Fourth, taxonomic barriers relate to specific aspects of the bird's morphology or condition that affect identification. Barriers may interact and are not necessarily mutually exclusive, nor do they all relate to species identification, but rather the broader practicalities of taking action on songbird IWT. Further, not every barrier will exist for every agency, e.g.. the police may experience different obstacles to BKSDA.

Table 3.1: Categories of barriers impacting conservation law enforcement (CLE) specific to songbird trade in Indonesia include legal, cultural, operational, and institutional factors across the enforcement stages of overarching, monitoring, species identification, and prosecution (Figure 3.1).

	Barrier			
	Legal	**Cultural**	**Technical**	**Taxonomic**
Overarching	Too many species listed (575) (BKSDA_7, BKSDA_17)	CLE officials falsify documents or certificates (KAR-1)	The government is not updated with science (NGO_IND_2)	Experience: gets easier over time the more identifying you do (POL_5)
	Implementation gap between central (Jakarta) parliament and regional government (BKSDA_17)	Leaders violate regulations (BKSDA_4)	Staff shortages (GAKK_14, BKSDA_17, BKSDA_16)	Skill: only a few officers can identify birds (KAR_6, BKSDA_17)
	Rules and regulations are unclear and not updated (POL_3, ACA_IND_1, NGO_IND_2)	Officers' perceptions of what is protected vary (BKSDA_8)	Lack of equipment (BKSDA_9)	
		CLEOs also keep protected birds (BKSDA_8)	Lack of general enforcement capacity (POL_5, BKSDA_6)	
Monitoring	No permits are required to trade in protected birds at markets (BKSDA_6)	Being bribed by traders to ignore lack of/false permits (POL_2)	No standardised or mandatory training (BKSDA_17)	Folk taxonomy: different trade names (BKSDA_4), or use of codes not names (BKSDA_17)
			Lack of actions such as patrolling (POL_5)	
			Traders mix the protected and unprotected birds (POL_1)	
Identification	Targetting intermediaries and intercepting in transit preferred interventions (NGO_IND_3)	Fear of identifying wrong in case incorrect identifications could lead to legal trouble (BKSDA_17)	Bird names are misspelt in reports and names change in regulations (BKSDA_4)	Morphological similarity between birds (BKSDA_4, GAKK_4, BKSDA_4)

	Traders might know more than CLE in terms of species identification (BKSDA_17)	Manual methods such as books are too slow- (KAR_1, BKSDA_2)	Difficulty: some species are easier to identify than others (GAKK_1)
			Familiarity: people can identify local birds but not from other areas of Indonesia (KAR_7) or frequently traded species but not rarer ones (BKSDA_4)
			Age: differing appearances due to moulted feathers (BKSDA_20)
Prosecution	Thugs/agencies shield perpetrators from criminal proceedings (BKSDA_9)		

3.5. Discussion

We have focused on analysing law enforcement practices related to songbird IWT, and their interaction with the wicked characteristics of the trade. While we explore a range of barriers that impact the efficacy of this practice (i.e. successful songbird identification) and enforcement under a punitive legal model, we acknowledge that it is a complex and multifaceted issue, which interacts with other issues and processes, and which is never truly 'solved'. This complexity underscores the need for a comprehensive approach, as there is no ideal solution to the songbird trade problem and that species identification is more than just a technical problem but also a standalone wicked problem. Although the songbird trade has experienced greater political attention in Indonesia over the last few years, here, we focus on what pushes species identification down the agenda in terms of enforcement priorities and influences. We provide a detailed description of the perspectives of a diverse group of law enforcement officials who are engaged in the policing of the songbird IWT in Indonesia. Those perspectives reveal important details about the law enforcement praxis around IWT, particularly the inter-agency relationships and the strong emphasis on social and cultural processes within enforcement. Finally, we are able to situate the taxonomic challenges within the broader set of barriers to the effective regulation of IWT in this case study, comprising legal, cultural, technical and taxonomic barriers.

3.5.4. Overall praxis regarding preventing songbird IWT

We present evidence for a wide range of formal and informal elements that form law enforcement praxis. These elements include a soft initial approach to enforcement based on social contact, complex in-person and online evidence-gathering techniques, the use of social networking applications to share information across agencies, and web searches to inform decision-making over species identification. Participants raised issues such as limited resources, inadequate training, corruption, species diversity in marketplaces and misidentification, and the complexity of governance structures. We also find that there are areas of uncertainty in praxis, where CLEOs need to carefully manage relationships with traders to acquire information and are aware that the success of subsequent legal cases may rest on complex taxonomic decisions.

"Socializing" ("socialisasi") involves the use of social programming by government employees to educate local people about regulations, allowing them to clarify how national and international policies relate to local practices (Cahill 2020). Cautioning first-time offenders rather than issuing fines could indicate a flexible use of authority and offer people a second chance (Runhovde 2016). The use of 'socialisasi' corresponds with local calls for criminal justice approaches to IWT that focus on surveillance as a deterrence method, rather than prison (Adhiasto et al. 2023). This form of alternative enforcement is also found in the "adat" (customary) laws in Indonesia that govern the system of marine protected areas (MPAs). While formal, national regulations involve carceral punishments and fines for crimes related to the MPAs; adat law favours enforcement based on local, Indigenous customs such as exclusion from the sea or village (Trialfhianty et al. 2023).

3.5.5. What would better species identification do?

Fundamentally, better species identification does not automatically translate into improved enforcement outcomes. While identification is essential for various purposes, like trade monitoring, conservation, quarantine, and animal health; these goals often overlap and compete. This multiplicity of institutional remits and objectives reflects the wicked nature of illegal wildlife trade (IWT), where species identification becomes both a technical and political act. The subjectivity of identification across actors, what species are prioritized, how they are recognized, and by whom, illustrates how taxonomic uncertainty is entangled with the broader complexity of IWT governance.

Species identification is critical when CLEOs engage with suspected offenders of the P106 conservation law, whether in physical marketplaces or online platforms (Figure 3.1), but not for the quarantine law. Current identification practices are slow, inconsistent, and reliant on a patchwork of manual and digital tools (Table 3.1). Our identification exercise (Figure D1) revealed that only 30–40% of species were correctly identified, with most CLEOs lacking confidence in recognizing certain commonly traded birds. While officers in Jakarta had received some training, those in Pontianak had not, reflecting uneven capacity that may correlate with the known volume of trade (Chng et al. 2015). Further, there were no formal expectations for CLEOs to develop taxonomic expertise over time.

This lack of taxonomic expertise mirrors broader trends in conservation policing; for instance, in work with rangers from the Mozambican Environmental Police, Massé (2022) found that staff were usually trained in anti-poaching or conservation law enforcement rather than ecology. A study on police investigations of illegal wildlife trade in Norway (Runhovde 2017) suggested that 'fewer resources are allocated to education about environmental crimes, which prevents new crimes from being detected and investigated'. Whilst it was evident that CLEOs could be better at bird identification, it may not be a realistic expectation -as one NGO member commented, 'we cannot force the police to do expert-level identification. It's hard for them' (NGO_IND_2).

However, in practice, species identification is embedded within the very wickedness of IWT as a problem. As shown in Figure 3.1, even when identification improves, it does not necessarily influence downstream decision-making, such as building legal cases or pursuing prosecutions, due to persistent institutional and procedural barriers. These broader constraints are detailed in Table 3.2, which outlines the systemic factors contributing to low enforcement rates. In terms of prosecution, taxonomic experts are required to provide evidence in court verbally (United Nations Office on Drugs and Crime 2022). Seizures and arrests are reliant on financial support, Sherman et al. (2022) reported that NGOs supplement government efforts on orangutan crime through detection and support for investigating and prosecuting cases. Thus, while species identification is a critical component of CLE practice, its impact is shaped by, and often limited by, the wider enforcement ecosystem. These dynamics are not unique to Indonesia's bird trade but are echoed across global IWT contexts.

3.5.6. Legal reform

Here, we outline the legal implications of inadequate species identification and explore how better species identification might open up different legal reform options. The existing dearth of identification capacity (slow process, lack of experts) could explain the seizure surge based on the quarantine law rather than the wildlife law. In Sumatra, a major hotspot for bird trafficking to Java, it was recently reported that 95% of birds seized were unprotected species (Guciano et al. 2024, p.4). This may be because CLE are pressured to 'choose the most straightforward charging option and close a case quickly' (Runhovde 2017), which appears to be using the quarantine law (Figure 3.1). The reliance on this law could also be due to a lack of resources (technical barriers, Table 3.2), the volume of cases, or the fact that it is easier to confiscate everything rather than identify individual species in the field in a limited time. The heavier use of the quarantine law means that enforcement happens along the trade chain rather than at places where trade is most concentrated, such as marketplaces (legal barriers, Table 3.2). The problem with more seizures under this law is that 'skipping' species identification before seizing still means CLE has to identify the bird for rehabilitation (Wyatt et al. 2022) or release. More seizures come with complications, such as limited facilities to house seized birds (Nijman et al. 2021). In some cases, birds are euthanised (ACA_OUT_1), a practice also reported for undocumented birds seized in Norway (Sollund 2022). On the other hand, even though it is less effective for monitoring trade levels and diversity, the use of the quarantine law could show that songbird trafficking is being treated as a more serious crime given that the Quarantine law has a penalty of up to 10 years in prison (Dang et al. 2021), whereas the conservation law currently only has a maximum of 5 years (Guciano et al. 2024).

Still, even if better species identification were available, some academics critiqued that 't*his whole trade is so difficult to tackle…it's a huge grey area. There are unclear rules and regulations…it's [songbird trade] accepted, and normalised*' (ACA_IND_1). To illustrate the scale of the problem, Nuruliawati et al. (2023) recently estimated that 175.7 million songbirds are kept by up to 87 million people, 35% of the total Indonesian population. Other IWTs that are complex in terms of diversity are reptile or tarantula trade (Rivera et al. 2024) or cacti and succulent trade (Margulies et al. 2023). In terms of grey trades, relating to identification and loopholes in legislation, the European caviar trade is a good case study of this (Dickinson 2022). To look to other IWT research, for instance, in seal trade in Dagestan, the fact that processed seal products look different from their original form often means that identification of legality cannot be carried out by visual means alone (Svolkinas et al. 2020). The fine-grain identification of Schreger lines is a major barrier to identifying between real and fake ivory (Venturini and Roberts 2020).

3.5.7. Social acceptability of songbird trade

There were concerns that law enforcement does not target the 'right' individuals: '[they] may only target about 10% of the important targets…only intermediaries are being arrested…not the main actors' (NGO_IND_3). In work on European eel trade in the EU, Gutierrez and Duffy (2023) found that greater enforcement attention was directed to foreign organised crime networks rather than legal businesses involved in illegal trade. Thus, biases that can be evident in enforcement also add another layer of wickedness to what from the outside may seem like a straightforward issue of identifying IWT, then prosecuting the human actors responsible for enacting it.

These biases point to multiple perspectives and value systems amongst actors such as law enforcement as a feature of wicked problems and IWT (e.g. cultural acceptability). The social acceptability of bird trade is based on differing values placed on birds than those derived from a conservationist lens. A prevalent barrier to species identification is taxonomy (Table 3.2), thus social acceptability for IWTs overlap with species identification issues in terms of how birds are identified - the features. For instance, to a conservation biologist, the unit of taxonomy is around species, but perhaps to a songbird person it is the ability to sing, or species that appear to be the same colour. Thus, folk taxonomies amongst the birdkeeping community, at first glance are a challenge for species identification, but these taxonomies exist in the first place due to bird trade's social acceptability.

As with other instances of IWT (e.g. Caspian seal IWT, Svolkinas et al. 2023), the fact that Indonesian bird trade is seen as socially acceptable may enhance the likelihood of corruption (amongst CLE or other government officials). For instance, earlier this year in West Kalimantan, a customs official was found with more than 500 birds at their house (Purnawati 2024). Dickinson (2022) calls this the 'corrupt upper-underworld', where 'upper' state actors like CLE engage in 'underworld' activities like IWT. Further, CLEOs clearly understand the rationales for why people would engage in songbird IWT, such as livelihood and necessity. It is also plausible that songbird IWT is not considered a 'serious' enough crime, largely because of this social legitimacy or even hierarchical speciesism towards songbirds (Gutierrez and Duffy 2023). Gakkum might only deal with the more significant cases of wildlife trafficking, such as tiger, rhino and orangutan trafficking (Sherman et al. 2022), which are on the government's high-priority list, whereas no songbird species are on this list (Adhiasto et al. 2023). Since many species are protected, traders may look to certain methods to pass off certain bird species either to evade detection or to make more money. To illustrate this, Nijman et al. (2017) reported that a Bali Myna, Leucospar rothschildi was offered for sale at the Pramuka bird market, whereas it was actually a Black-winged Myna, *Acridotheres melanopterus* with its yellow eye patches coloured blue.

If faster species IDs were available, this may provide more capacity to keep up with the magnitude of songbird IWT. Still, formal enforcement may not affect legal compliance. Working with Norwegian fishers on social norms and compliance, Gezelius (2002) found that formal enforcement was not a primary reason for compliance or hiding violations. Instead, fishermen complied due to fears of "being the object of 'talk'" in the community and of their moral convictions (Gezelius 2002). Marshall et al. (2021) found that fear of prosecution among Indonesian birdkeepers was minimal and that the level of openness was high. If formal enforcement were to be strengthened with greater species identification capacity, the risk of being detected by enforcement authorities would increase. Still, it is not known if compliance or the level of enforcement is the reason why birdkeepers do not fear prosecution.

If we accept an enforcement-based conservation model for addressing songbird trade, i.e., using enhanced enforcement to address high rates of illegal and unsustainable trade, increasing personnel and staff and providing equipment may help lower these rates and improve enforcement efficiency. Indeed, understaffing at ports was noted: 'in Tanjung Perak Port [Surabaya, Eastern Indonesia); there are only three people… In essence, it's about smart work' (BKSDA_16). Surabaya, a 'logistic centre for birds incoming from Kalimantan and eastern Indonesia (Guciano et al. 2024, p.21), had 450 monthly port calls in 2015, averaging 15 daily boats (Merk et al. 2017). Between 2015 and 2017, Gakkum had an annual budget of US$13.7 million, which in places such as Papua only allowed for one police officer per 500,000 hectares (Dang et al. 2021). Thus, any improvement to species identification processes is reliant on funding for more personnel to actually do the identification, that may not be available.

3.5.8. Concluding remarks

Here, we provide new information on how challenges faced by law enforcement contribute to the wicked aspects of the illegal songbird trade in Indonesia, as an example of wider challenges to IWT management. Species identification is more than just a tame or technical issue, but part of the wicked problem of addressing IWT in Indonesia and beyond. While our focus was on the process of species identification within enforcement praxis, discussion of taxonomic challenges raised a variety of wider issues that give a more holistic picture of the ways in which the laws are enforced and the rationale underpinning those approaches. Taxonomic challenges sit alongside and interact with legal, cultural, and technical barriers, as articulated by the CLE based on their experiences. However, we conclude that a lack of species identification capacity, accuracy, and speed is at least partly responsible for low rates of songbird IWT detection, prosecution, and a dearth of reductions in wild bird harvesting. The inability of CLEOs to adequately identify traded species leads to two (not mutually exclusive) options for future enforcement: first, a greater investment of resources in identification so that punitive approaches can be employed to remove offenders and deter others. Second, an acknowledgement that taxonomy is technically hard but also wicked in and of itself, and that the problem cannot be tackled adequately, with a resulting shift of resources into "socialisasi" approaches that try to remove the problem without ever quantifying the extent of that problem. Together with our participants, we suggest the following areas for exploration as potential improvements to address the barriers that the participants identified (Table 3.2, though not necessarily in order of priority). Whilst these priorities are outlined for Indonesia, they are transferable to other IWT cases:

1: More formal training in species identification, from BKSDA or the broader Ministry of Environment and Forestry, for CLEOs. This need not be to the point of being an expert, though the process and discussion of species identification does at least encourage discussion and collaboration between agencies.

2: Exploratory co-design of taxonomic aids, working under the assumption that genetic methods are beyond CLE's resources but that other technological options might work for a visually distinctive group, such as many traded songbird species. This aligns with existing technology use for some species identification in the field (e.g., Google Lens).

3: Evaluation and greater study of approaches in which law enforcement engage with and educate those involved in IWT – for instance, the "socialisasi" approach - to compare against more punitive approaches, and exploration of wider use of these approaches.

3.6. References

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Adventures in focus groups and the Indonesian language

Not all my ideas worked in the focus group discussions (FGDs). In Indonesia, oleh-oleh is a form of snack/souvenir, and field collaborators told me it would be nice to bring something from Leeds. The only thing I could think of was Yorkshire parkin, a famous gingerbread cake made with oatmeal and syrup, which from a particular shop in the Corn Exchange (Leeds city centre) can last up to two months. some people liked it in focus groups, others not so much… But doing the first set of focus groups helped build my resilience. I learnt to accept my failures; not everything works out, and that's also ok; it can still contribute to your results. Sometimes, my language skills were embarrassing; I first started saying the word for seizures in Indonesia I was talking about medical ones rather than the trafficked animals. In my attempts at decolonial research, I have tried to cite Indonesian authors in English and Indonesian journals.

Enforcing the law in this kind of complex situation is a challenging job. In workshops, I wanted to explore the everyday experiences of conservation law enforcement, how they enforce the laws, and how they identify different bird species in often challenging environments. It became clear that complex factors were making even the idea of technology a difficult issue, ranging from the overwhelming task of identifying the many different birds to the fact that the social aspect of the marketplaces often plays an important part in the local community.

Chapter 4. Designing user-centered technologies to address the illegal wildlife trade

4.1. Abstract

Species identification by law enforcement is an important part of managing the illegal wildlife trade (IWT). In this paper, we explore how technology might influence the policing of IWT by improving species identification in the illegal songbird trade in Indonesia. Conventional top-down technology design may miss the crucial insights of end-users to define the functionality (e.g., feasibility, usability) that would facilitate integration into practice. Instead, our approach actively involves law enforcement end-users, incorporating their valuable insights and centering the process on their experiences, thereby increasing the likelihood of adoption. We show how technology can be developed using a user-centered design methodology to explore a (hypothetical) automatic species identification app to monitor songbird trade. Indonesian law enforcement officers were positive about using technology, and there was a consensus that this could improve species identification. Using technology as a stimulus for reflection on broader challenges in law enforcement, we reveal how technology might operate as a component of a complex solution to songbird IWT. We also found barriers (such as the social acceptability of bird trade, risks of corruption and co-option by traders, and requirements for verbal evidence regarding species identification in court).

4.2. Introduction

Legal and illegal wildlife trade (IWT) are multibillion-dollar industries and pose a significant conservation challenge involving hundreds of thousands of species of animals, plants, and fungi (Phelps et al., 2016). Though IWT itself is sometimes difficult to identify and distinguish from legal trade, ~24% of all terrestrial bird, mammal, amphibian, and reptile species are traded globally (Scheffers et al., 2019). IWT has been described as a wicked problem because it is ill-defined (Arroyave et al., 2023) and embedded in complex social-ecological systems spanning many issues (Thomas-Walters et al., 2020).

Technological solutions are attractive for tackling IWT because they offer opportunities to promote legalistic interventions in settings where law enforcement already occurs (Hu et al., 2023). The dominant discourse in conservation technology is technological determinism – the assumption that developing technology automatically equates to developing solutions in a linear manner. This deterministic attitude leads to assumptions that technology will aid conservation, even when evidence for this is missing, in her political ecology of IWT and surveillance technologies, conservation professionals suggested 'people want to fund drones, even if they do not work' (Duffy, 2022). IWT technologies are a subset of conservation technologies. We define them as tools designed to support law enforcement, conservation practitioners, and members of the public in combating wildlife trafficking. The targeted end-users of IWT technology are often conservation law enforcement (CLE), which Massé (2020) defines as "the organised practices and authorities used to enforce laws and norms related to the use of biodiversity and the regulation of activities within spaces of conservation".

Technologies can play various roles in counteracting illegal wildlife trade, including co-opting existing technology for CLE (e.g. using X-ray machines to detect concealed organisms at airports (Pirotta et al., 2022), or genomic analyses to trace the source of products (Gouda et al., 2020)). However, here, we consider custom-built technologies used as taxonomic aids (resources that help identify species) in policing IWT. Taxonomic aids can enhance the physical detection of IWT, such as the trafficking of protected species (t'Sas-Rolfes et al., 2019). Identifying species visually, rather than forensically, is a relatively cheap and accessible option for detection. Such aids can now be deployed readily on mobile phones due to their increased prevalence and computing power (Lahoz-Monfort & Magrath, 2021).

Most of the development of technological taxonomic aids for IWT have been mobile apps that function as digitized decision trees for IWT detection, akin to species identification keys (Kretser et al., 2015). To arrive at species identification, the user makes a series of decisions based on characteristics such as colour (e.g. TankWatch) or form, (e.g., scales, fur, or feathers) (e.g. WildScan and WildALERT). Automatic, optical recognition approaches for IWT enforcement go beyond decision support to attempt direct identification based on training data. Such approaches might be useful for border and customs control, which receive high-volume trades (such as songbird or reptile trafficking), trade in rare species (for instance rhino, ivory and insect trade such as tarantulas (Rivera et al., 2024)), and look-alike trades (e.g. succulents, cacti (Margulies et al., 2023) or sharks (CITES, 2023)). Though not widely used in practice, one notable innovation is 'SEE Shell', a tool which uses an artificial intelligence (AI) model to differentiate between real and fake tortoiseshell products from photos (SEE Turtles, 2022).

Attempts to design IWT technologies have often focused on hackathons and philanthropic projects (Joanny, 2020), inspired by techno-centric rationalities (Crandall et al., 2021). However, one problem with techno-centric approaches is that they are driven by the technological 'elite' (Haklay, 2013) and often lack user perspectives, social context of use, and knowledge of real-world practices.

Techno-centric approaches frequently result in technologies fading out due to a lack of investment (Galaz et al., 2010), user motivation (Thies, 2015), or user-friendly designs (Fitton et al., 2018). These outcomes are often caused by a lack of user involvement due to resultant technologies being made for, rather than with, end-users.

Currently, common interventions for IWT do not promote engagement between relevant parties (i.e. law enforcement versus consumers and harvesters or conservationists). By maintaining the isolation of different groups of actors, such interventions merely strengthen the existing systems of punitive enforcement to combat IWT (Wilson & Boratto, 2020). While some tools are effective in identifying species, the existing integration of technology into IWT enforcement has not had an obvious impact. It is unclear if IWT technologies have used end-users insights during the design process, though some, like SEE Shell, were created at the request of law enforcement (SEE Turtles, 2022). Still, conservation technology partnerships such as WILDLABS have made progress in publishing failures in the field regarding deployment but not necessarily design (Cornell & Warren, 2021; Loucks & Becker, 2021). Learnings from the Information and Communications Technologies for Development (ICT4D) sector have highlighted the uneven politics in ICT4D research, its neoliberal orientation, techno-optimism and embedded Eurocentric worldview, along with the suggestion that these technologies have not produced tangible benefits for the people they claim to help as many ICTs are ‘too narrow and short term in their design’ (Schelenz & Pawelec, 2022). However, others discuss framing ICTs around justice rather than development (suggesting countries where ICT4D needs to be ‘developed’), which can be applied to the context of songbird trade. Further, recent incorporations of Indigenous, queer and feminist understandings of ICT show the field’s renewal and openness (Masiero, 2022).

Joanny (2020) listed several solutions to improve the design of conservation technology, one of which is to ‘directly engage end-users and key stakeholders…in technology design from an early stage to ensure it is fit for purpose’. One way to directly engage end-users is to use a co-productivist (CP) and participatory design (PD) approach. Omrow et al. (2024) argue for a ‘co-productivist approach’ that acknowledges the mutual shaping of social factors (like values, norms, and governance) and technological systems through their interactions. Participatory design was developed in Norway as a process for bringing end-users and other relevant parties into the design process (e.g. for software design and urban planning (Dalsgaard, 2012; McGinley & Nakata, 2012)) to decide what problems must be solved and how (Hagan, 2019).

The CP/PD approach explicitly acknowledges that the success of technologies is determined by the conduciveness of the socio-political context within which they are introduced. In theory, the CP/PD approach bypasses the technological determinism that makes some solutions impractical (Duffy, 2022, p. 150). Understanding the social context in which any IWT intervention occurs is crucial for effective, efficient and just interventions, particularly for trades that experience widespread social acceptability (Hampton & Teh-White, 2019). The CP/PD approach incorporates ethical implications, biases, and diverse user needs into technology development, providing space for different approaches, such as the insertion of feminist values. This insertion allows for the interrogation of political context, the power structures and the social norms that help to shape practices and provide insight into how technology can conform to, exacerbate, or disrupt these structures.

Songbird trade in Indonesia represents a significant conservation challenge, with over 500 species of birds being traded (Fiennes et al., forthcoming). Southeast Asia, particularly Indonesia (Marshall et al., 2020), is a global hotspot for bird trade, with the IUCN declaring an ‘Asian Songbird Crisis’ (Sykes, 2017). While CLE have more field exposure than the layman, formal species identification training is rare (Lee et al., 2005). As a result, species misclassification is a barrier to prosecutions, contributing to the failure of over 70% of wildlife crime cases (Gouda et al., 2020).

Despite the potential for technology to support species identification, especially through tools like image recognition, there is limited understanding of how such tools could be effectively integrated into CLE practice. Existing technologies are often developed without input from end-users, which can limit their usability and adoption in real-world enforcement contexts. To address this gap, we use the Indonesian songbird trade as a case study to explore how technology might support CLE efforts. Specifically, we conducted a preliminary assessment of a hypothetical mobile app that uses machine learning to identify traded songbirds from images. Our aim was twofold: (1) to evaluate the potential of such a tool to support species identification in the field, and (2) to understand how CLE officers might use this technology in practice. Building on earlier findings that Indonesian CLE officers are already experimenting with general AI tools like Google Lens for species identification (Fiennes et al., in review), we adopted a user-centered design approach. This allowed us to engage directly with end-users to explore not only the technical feasibility of species recognition tools, but also the social, cultural, and ethical considerations that shape their use.

4.3. Methods

Building on prior focus groups with Indonesian CLE agencies (Fiennes et al. in review), we explored CLE agencies attitudes to existing technology use and their appetite for technology design in user-centered sessions. In these sessions we discussed a mobile phone app to identify songbirds (a taxonomic aid), where this technology might fit into CLE's work and what barriers technology could and could not overcome. User-centered design (UCD) (a subset of participatory design) refers to design which focuses on end-users' needs and wants (Chun et al. 2015), though we, the researchers, rather than our participants, identified the potential for AI tools to assist with songbird species identification in the field.

4.3.1. Overall session information

We conducted one round of focus group data collection in each of five cities within Java (Jakarta, Bandung, Yogyakarta, and Surabaya) and West Kalimantan (Pontianak), renowned for their role in the bird trade (Chng et al., 2015, 2016; Chng & Eaton, 2016; Rentschlar et al., 2018). We invited the main agencies involved in songbird IWT enforcement; the conservation agency (Balai Konservasi Sumber Daya Alam, BKSDA), Agricultural Quarantine (Badan Karantina Pertanian, referred to as "Karantina" by members of the agency and therefore abbreviated to "KAR"), the wildlife law enforcement bodies such as GAKKUM (the Law Enforcement Division of the Ministry of Environment and Forestry), and the local and regional police (POLRES). Overall, there were 57 participants across all the focus groups, ranging between 8 and 13 per discussion. Participants were recruited by sending terms of reference and invitation letters to the head of each agency, through Yayasan Kausa Resiliensi, the local NGO we collaborated with. In this invitation, we suggested that field officers who would be tasked with species identification as part of songbird trade monitoring efforts were sent. With a few exceptions in the Quarantine and BKSDA agencies, most of the participants were men of varying ages. Participants were not randomly sampled since the selection was at the agency head's discretion, though we had at least three participants per agency in each session, except for the police, from which one or two participants usually attended. Therefore, a range of staff from different levels and hierarchies within organizations attended the sessions. Before the study commenced, we asked individuals for free, prior, and informed consent (FPIC) and all participants were remunerated for their time with a per diem fee.

Our method differs from a full technology assessment since it is not constrained by the final goal of realizing a technology product, therefore it constitutes a preliminary technology assessment instead (detailed in Figure 4.1, with specific questions that participants were asked in the Appendix B Guide

1). Phases 1-2 (Figure 4.1) were conducted and elaborated in an earlier publication where we explored CLE's general practice and barriers they experienced (Fiennes et al. in review). For characterizing use cases we had three objectives, understanding current uses of technology, determining some potential use cases, and identifying desired technological features. The following four methods were used for Phase 3 (Figure 4.1). The full description of prompts to participants can be seen in Guide 1 in Appendix C.

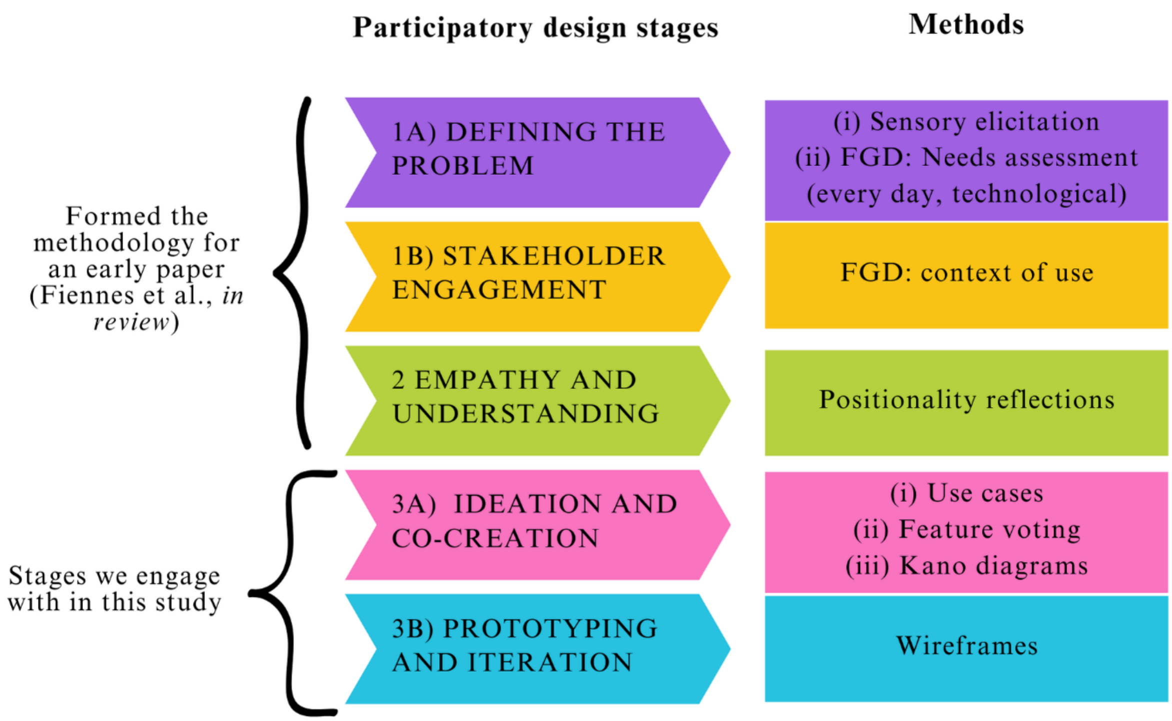

Figure 4.1*: A three-stage workflow with associated methodology for each participatory design stage; focus group discussions (FGDs) (1-2) with Indonesian conservation law enforcement and user-centered design sessions (3). Stage 3 is the stage of participatory technology design that we explore here, excluding the latter stages of implementation.*

1. Overall use cases: We asked users broad questions such as what do you need technology to be able to do? How do you need to use a taxonomic aid? We chose to focus on using a taxonomic aid at a marketplace. Marketplaces are usually where the greatest number of bird species and individuals are present at any one time, and are often reliable sites to infer wild population health for traded species (Eaton et al. 2015). The marketplace setting also allowed us to explore factors that could influence the adoption of this technology by end-users.

2. Feature Voting: Beyond species identification, we prompted CLE on examples of features that could accompany a taxonomic aid used to enforce legal songbird trade, e.g. IUCN status and local names (Figure 4.3). Drawing on creative methods (Kara 2015), we employed concept mapping and feature voting to prioritize features for the app, asking participants to rank desired combination information using post-it notes.

3. Kano diagrams: We used Kano model diagrams to organise features discussed by end-users . Kano models help assess design features based on basic functions, performance, and delight attributes (Buley 2013, p.116). Traditional axes include impact versus cost, or essential versus delight. In our case, we used impact and feasibility (benefit). For example, detecting birds by sound might be impactful for identifying rare species but is less feasible in noisy marketplaces.

4. Wireframes and black hat sessions: Wireframes allow researchers to test early design concepts, identify potential gaps, and discard ideas that do not resonate with end-users (Babich 2017). We used wireframes created with the software Balsamiq (available at https://balsamiq.com/) to help participants explore the design and feasibility of solutions through simple, low-fidelity diagrams (Buley 2013, p.193) of user interfaces (Figure 4.3). Drawing on Buley's (2013, p. 199) concept of 'black hat sessions', participants critiqued the wireframes by assuming the role of a critical, time-pressed user, helping to identify potential usability issues.

4.3.2. Data triangulation

Where necessary, we used one-to-one semi-structured interviews with academics and practitioners to triangulate the data from CLE and help to supplement any gaps in our understanding of songbird trade governance and the role of technology. Interviewees (academics, ACA and conservation practitioners from NGOs) were compensated with a standard hourly rate and were also asked for their FPIC. Academic (ACA) and NGO (NGO) codes are based on location, e.g., "ACA_OUT_1" for outside and "ACA_IND_2" for inside Indonesia.

4.3.3. Data analysis

We analyzed the qualitative data from user-centered design sessions using NVivo 11 qualitative software to organize the emerging codes and reflexive and analytical thinking processes (e.g., memo writing and a record of field notes) (Aujla 2020). Direct quotes are italicized, while paraphrased quotes are in normal font. Participant codes use the agency abbreviation (BKSDA, GAKK, KAR, POL) followed by a number, without matching the agency to the session location to ensure anonymity. Subsequently, we undertook a thematic analysis, employing inductive coding using grounded theory principles (Newing 2010, p.6) to explore themes around bird crime, sustainable trade, and their combined consequences. User-centered design sessions, conducted in Indonesian and were recorded and transcribed by field collaborators and later translated using online tools and support from the research team. Interviews were primarily conducted in English and later transcribed.

Our methods received ethics committee approval from the University of Leeds (AREA FREC 2023-0419-521) and were conducted under a research permit (311/SIP/IV/FR/11/2022) from Indonesia's National Research and Innovation Agency.

4.4. Results

4.4.1. Existing uses of technology

Participants expressed that they already used digital technologies to conduct aspects of their work. For songbird identification, they used Google Lens (automatic, based on machine learning) and Burungnesia (decision tree based). One participant used BirdNET, which uses machine learning to identify birds by sound, though '*BirdNET requires the internet…it is not very effective'* (BKSDA_12). Separate to songbird-related enforcement, CLE used *'plant applications for analyzing vegetation*' (BKSDA_4). Quarantine uses physical technologies like '*a mobile X-ray, but its usage still requires permission from the airport authority beforehand'* (KAR_9), to check luggage for concealed flora and fauna. Quarantine also uses iQFast, a system that makes it possible to monitor the flow of agricultural commodity traffic in real-time (Setiawan et al. 2024) and *'can at least trace who sent and received money [for the permit]'* (KAR_1). The police also designed a system for the public to report IWT (for instance, at a marketplace), known as e-Laporan (e-reporting), *they can send an email, attach the photo evidence, and it will go to the server'* (POL_3).

4.4.2. Broader (non)use cases

Table 4.1 summarizes the main advantages and disadvantages of the use of technology. The main advantages of using technology for CLE would be ease of use, speeding up identification, improving identification accuracy, providing training to officers and educating both traders as part of their existing persuasion and socialization (education) campaigns, and unaware members of the public. The challenges that may hinder technology adoption by CLE include low light conditions and poor-quality cameras that impact image clarity, as well as the reliability of technology. Indirectly, issues such as risks of hacking, altering relations with trade actors, and changing traders' way of working could impact the effectiveness of technology in CLE efforts (Table 4.1).

Table 4.1: Adoption factors (advantages and disadvantages) of using technology (shorthand as tech) for bird identification in the field, as identified by Indonesian conservation law enforcement (CLE) agencies. Quotes from NGO staff and academics are included to triangulate and enrich qualitative data from law enforcement. See text for abbreviations.

Adoption factors			**Example quote**
Advantage	Direct	Ease of use	Tech is better than other ID methods because it is easy to use (BKSDA_4).
		Speed	Tech can help agencies ID birds quicker and more efficiently (KAR_1, GAKK_12). Current delays of up to three days for species ID (NGO_IND_6).
			Quarantine needs to process animals quickly. If they cannot determine a species ID, they postpone it (KAR_9).
		Accuracy	Tech could ID birds better than humans, even up to 99% if possible (KAR_3).
			It could reduce human error in quarantine certification (KAR_6).
	Indirect	Socialization	Socializing and informing traders that this tech has been implemented (GAKK_12, BKSDA_3).
			Use tech to encourage traders to surrender protected birds to authorized institutions (BKSDA_3).
		Education	Educate the public on protected species (POL_5) and train CLE (BKSDA_6).
			Public use tech to ID birds and report IWT to CLE to save time, energy, and costs (BKSDA_17, POL_5).
Disadvantage	Direct	Signal & internet issues	The signal might not be reliable (KAR_10, BKSDA_22, GAKK_13).
			If you don't have a signal, you won't have real-time accuracy measures for ID (GAKK_7).
		Field & equipment issues	Insufficient light during photo capture can lead to misidentifying protected species (BKSDA_6).
			Low-quality cameras, such as on some phones (BKSDA_21).
		Reliability of results	Low confidence in the ability of tech to distinguish between cryptic species (ACA_IND_2, GAKK_13)
			Needs to be able to distinguish between captive-bred and wild birds (KAR_3).
		Hackers	Transportation permits for animals are still manual due to hacking risks (BKSDA_1, KAR_1).
			CLE might only have one central server for information storage (KAR_1).
	Indirect	Altering relationships	People at markets will be suspicious of NGO staff if they know they use tech for ID (NGO_IND_3).
		Changing the way of working	Traders might not openly display protected animals (BKSDA_3, BKSDA_4).
			Risk of trade actors coopting tech for their own species ID needs (KAR_2).
		Corruption	Risk of CLE leaking information about tech to traders (GAKK_14).
		Risks to livelihoods	Traders are more focused on profit than protecting wildlife (BKSDA_8).

4.4.3. Technological features

Ranking features by frequency and spatially in Kano diagram revealed a range of features that CLE believed would complement a successful species identification (Table 4.2, Figure 4.2). There was a consensus across agencies that certain information is useful, such as the Indonesian protection status, but a lack of consensus in the prioritization of other information sources amongst agencies (e.g., lack of agreement on the importance of sound to identify birds in marketplaces; Table 4.2, Figure 4.2). Even though the importance of sound was disputed, CLE may encounter situations where birds can be heard and not seen: *During patrols, sometimes we only hear bird sounds, and the hope is that this sound recording can be used to identify the bird through its sound.'* (BKSDA_4). Together, these results show a catch-all application may not fulfil specific needs or address each agency's unique barriers (Table 4.2, Figure 4.2).

Table 4.2: *The summary of features for a mobile phone technology that can be used to identify songbirds in trade, as generated by Indonesian conservation law enforcement. Features are ranked based on frequency, with the number of workshops where the feature was voted for in brackets.*

Features for an application	**Number of votes**
Indonesian protection status	20 (5)
Official Indonesian name	16 (4)
Specific characteristics	(3)
IUCN status	12 (4)
Local name	9 (3)
Size/morphometry	13 (5)
Sound	9 (5)
Origin	9 (3)
CITES status	8 (4)
Latin name	8 (3)
Distribution (description and map)	7 (3)
Standard image	6 (1)
Age	5 (3)
Feather colour	3 (2)
population numbers in the wild maybe the same as the IUCN status	1 (1)
Habitat type	1 (1)
360-degree/photos of the bird from all sides	1 (1)
Eggs	1 (1)
Sex	1 (1)
Penalty and threats	1 (1)
Subspecies	1 (1)
Bird behaviour	1 (1)

Bright/dark morphs	1 (1)
International trade name (could be the English name)	1 (1)
Molecular characteristics	1 (1)

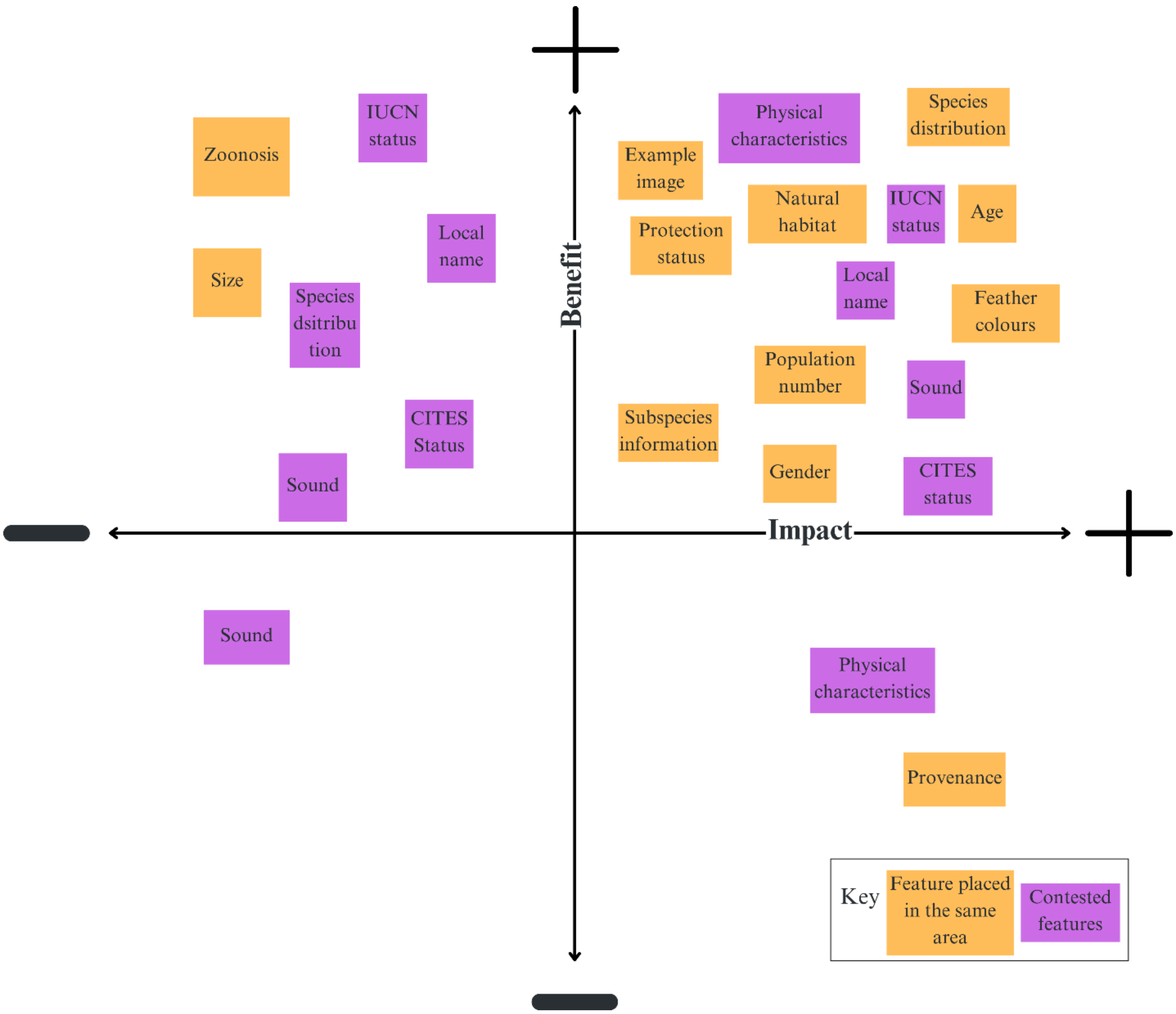

Figure 4.2*: Kano model diagram of potential features to go in a hypothetical mobile phone application for identifying birds in trade, discussed with Indonesian conservation law enforcement.*

4.4.4. Black hat sessions

We present a six-screen wireframe (Figure 4.3) that builds off the low-fidelity prototype we discussed in user-centered design sessions (Figure E1). The workflow featured is largely based on verbal and written contributions by participants. It opens with an introductory page with government accreditation (i.e. from the Ministry of Environment and Forestry).

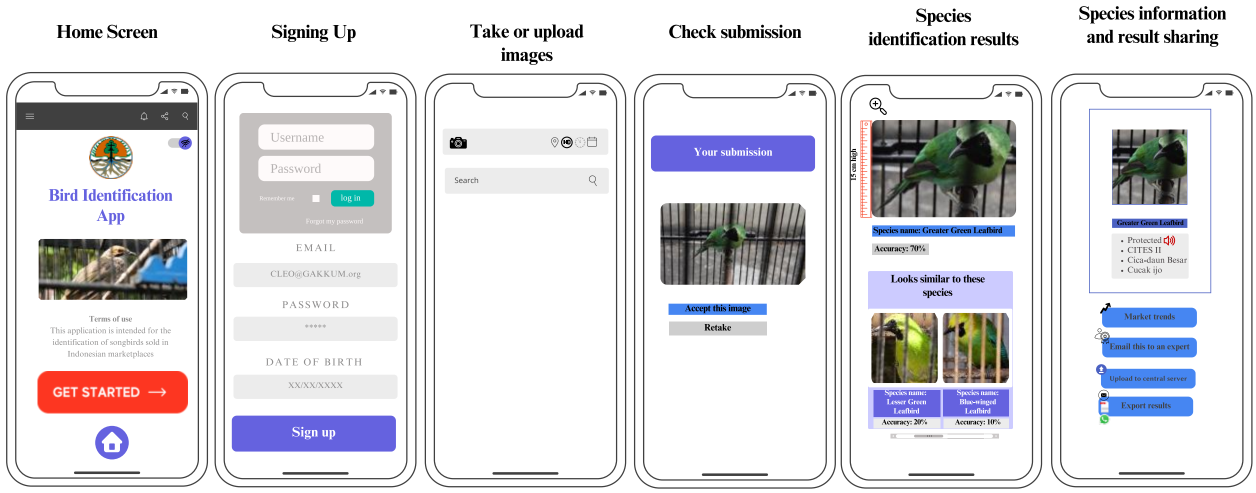

Figure 4.3 (A-F): *A wireframe diagram of a hypothetical mobile phone application that would use machine learning algorithms to automatically identify traded bird species in the field, where A through F represent steps during the use of the app. We derive data from user-centered design sessions conducted with conservation law enforcement in Indonesia who are tasked with preventing illegal songbird trade.*

End-users can read the terms of use, access a user guide on a default home page (Figure 4.3A) and have the option to use the app in offline mode so it can be '*usable in remote areas with limited internet connectivity'* (POL_8) (Figure 4.3A). On the second screen, end-users can sign up or log in (which may require a vetting process). After logging in, end-users can take a new picture of a bird, browse from their gallery, and manually specify the location, image quality, time, and date if offline (Figure 4.3C). Next, end-users can view the image they have taken and retake or select another image from their gallery (Figure 4.3D). Afterwards, they can view the identification result from the machine-learning model and see the three most similar species identified by the model (Figure 4.3E). One participant suggested that *'it would be helpful to have a comparison item like a cigarette or a pen'* (BKSDA_23), so we added a ruler (Figure 4.3E). The user can see the species name and top features from our voting (Table 4.2) and Kano model diagram (Figure 4.3) exercises: the species protection status and trade names (Figure 4.3E). They can then email the results to an expert for verification, which could also be done automatically if the top prediction from the model was lower than a pre-set standard (Figure 4.3F). This threshold for verification could be 90%, which is *'the success rate for BKSDA Pengendali Ekosistem Hutan [experts]'* (POL_6) (Figure 4.3F). Results could be uploaded to a server (automatically or stored locally, then uploaded when internet signal was restored) (Figure 4.3F). If it was a protected species, *the device could sound an alarm*' (GAKK_9). Together, this wireframe and feedback represent a shared vision for technology from law enforcement participants on how AI-enhanced technology could be used to recognize species in the field.

4.4.5. Critical reflections

Whilst the emphasis of our results was on the logical flow from user needs to design to iteration. We also want to share respondents' skepticism and resistance to technology articulated during the focus groups. Some had concerns about the development of AI tools such as collecting enough *'high-resolution photos from different angles, requiring at least 16 photos'* (BKSDA_17). Others lamented that '*it [technology] takes a long time to develop'* (GAKK_5, POL_4) and questioned the readiness of AI, which *'isn't there yet, but it might get there in five to 10 years'* (ACA_OUT_1). One participant questioned if end-users would be ready, saying that '*people are not skilled in using technology'* (BKSDA_8).

Others suggested improvements to the species identification process that did not focus on technology at all. Either they trusted the existing methods, suggesting that it was a matter of more training, or that visual methods were not sufficient for species identification (Table 4.1). For instance, one person said, *no tools are required, either a guidebook or browsing*' (BKSDA_4) or that *'if there is training for identification, it will be easy'* (GAKK_3). Others suggested marrying *'the names of protected animals already registered in P106…with…photos of each animal to facilitate identification based on the characteristics of the intended animals'* (BKSDA_21).

Fundamentally, CLE must *'consult an expert [for species identification], [and write a] berita acara [official report] for the prosecutor'* (KAR_3). Thus, any *'evidence we obtain from this technology cannot be used in court'*, but *'it will be useful for us who work in the field'* (BKSDA_6).

4.5. Discussion

Here, we have evidenced how a CP/PD methodology can reveal the context for the use of technology in practice and produce a detailed and nuanced product design by centering the design method on the end-users of that technology. We have demonstrated why these methods are helpful in this situation, by allowing end-users to speak about why technological interventions can work and how they can fail. CLE provided valuable insights into what information would need to accompany a particular tool, such as training and various field-friendly features such as offline modes and the ability to easily send identification results to their colleagues. Participants were also able to highlight potential barriers to the use of the technology, including the legal standing of evidence derived from the technology and concerns over how technology will affect existing strategies of enforcement, such as persuasion.

4.5.1. What is the role of technology in monitoring songbird IWT?

CLE was receptive to the imagined use of species identification technology for identifying songbird IWT. Together, we were able to build a clear wireframe (Figure 4.3) for a species identification tool that allows end-users to 'technologically leapfrog' (Lewis 2012) past various taxonomic barriers that complicate species identification, such as the volume of species sold, changing regulations and look-alike species in trade (Fiennes et al. in review). End-users generally framed the idea of using species identification technology as easier and faster than other manual and online methods (Table 4.1). This is encouraging for the advancement of IWT technologies in the field given that user motivation (Thies 2015) and engagement in technology discussions (Sintov et al. 2019) are often cited as reasons for the low uptake of conservation technology.

However, market surveys are not the target of law enforcement work (Fiennes et al. in review), and agencies may only have funding for a fixed number of patrols (Maulany et al. 2021). CLE's focus on indirect activities (like socialization with traders as part of community-based policing efforts) suggests that technology's role would be less about walking up to someone, identifying their bird, and arresting them, and more about communicating the introduction of taxonomic aids to traders as a deterrent. The existence of technologies and of themselves can function as a deterrent, as has been shown in the case of CCTV in urban crime (Gómez et al. 2021) and has been suggested (though with little empirical support) for IWT technology (Kretser et al. (2017), Table 4.1). Taxonomic aids might be more useful in customs contexts along the trade chain. For instance, Quarantine has hundreds of checkpoints for import and export and domestic movement of wildlife throughout the country (Guciano et al., 2024, p. 9); if officers stationed at these posts had AI -enhanced taxonomic aids, this may strengthen detection of IWT. Other actors might use the proposed technology in marketplaces, such as the NGO and academic community (Table 4.1), though these activities are normally more covert and risk breaching ethical boundaries to collect data on unsuspecting traders without their consent (Sandbrook et al. 2021).

4.5.2. Indirect benefits of tech: communication and education

Technology could address specific barriers in IWT enforcement, like communication between agencies, in addition to directing more formalized species identification services. In the black hat session, participants suggested features such as being able to send species identification results over WhatsApp, which they already use to communicate with colleagues about species identification (Figure 4.2). Saving model outputs regarding species identification will be useful for case building but can also be used for training opportunities across agencies. Others such as Muashekele et al.

(2019) and Ziegler et al. (2020) have demonstrated that conservation technologies can be effective in facilitating communication between relevant parties, and it is evident that species identification technology could be a medium to do this.

As well as internal communications, CLE also stressed that the tool could be used to provide awareness regarding protected species to potential consumers (Table 4.1) and to encourage the public to become whistleblowers on songbird IWT. Elsewhere, more formalized taxonomic validation and verification often occur in citizen science schemes, where automatic "flagging" is combined with subsequent manual verification by a pool of expert verifiers (e.g., eBird, Iliff et al. (2020)). However, even in the best-resourced areas of taxonomic work, such as the management of invasive species in the USA, there is a worrying lack of taxonomic expertise, and a similar use of informal systems of identification (Lyal and Miller 2020).

4.5.3. What are the barriers that can be solved?

Though some participants were skeptical about the use of technology in their work, this appeared to be more due legal, cultural and taxonomic barriers (explored more in depth in (Fiennes et al. in review)) or because of apprehensions like phone service issues rather than due to their resistance to the technology itself (Table 4.1).

If a species identification tool were to be available to Indonesian CLE, it would not be a one-size-fits-all approach, given each agency has a different remit and set of responsibilities. For instance, there was a lack of agreement amongst agencies regarding the information that should accompany a successful species identification (Table 4.2 and Figure 4.2). In theory, this limits the possibilities for implementation as each agency may require a different version. Still, since Indonesian CLE already reported having a high workload and funding challenges (Fiennes et al. in review), technology may resolve some of this stress (Oliver 2006). A taxonomic aid would increase the identification work that each person could do, so any application, even if not targeted at the agency level, would be useful, especially when species identification can take several days (Table 4.1). Though the use of technology could lead to automation, deskilling (Arts et al. 2015), and the erosion of tacit knowledge within law enforcement (Simlai et al. 2023), it does not seem that our participants were particularly concerned about the dynamics of their labour processes changing.

Some disadvantages (Table 4.1) associated with using technology to control IWT can be alleviated in the design phase (e.g., development of an offline mode) (Figure 4.3). Still, the possibilities of this must be balanced with phone storage constraints for large applications and the fact CLE are often using personal phones for work activities.

4.5.4. What barriers can technology not overcome?

Some disadvantages of technology adoption were more serious than others (Table 4.1). For instance, if the introduction of technology causes traders to change their modus operandi or they are tipped off by CLE (Table 4.1), then there is a limited use for species identification technology in the field since the protected species may be made less accessible to law enforcement. In an online setting, these circumventing behaviours have been alluded to, for instance, the use of code words to describe illicit items on online marketplaces for wildlife (Hernandez-Castro and Roberts 2015; Davies et al. 2021).

CLE were concerned about changing relationships with traders following the introduction of new surveillance tools. In a similar way, the introduction of body worn cameras in policing shifted the balance of power between police and public, and while there is mixed evidence for such an effect on policing (Lum et al. 2020) and there is a tension over who can use the apparently objective technological tools (Houwing and Eck 2020).

There are some tasks that image-based technology will simply not be able to carry out with any consistency, like clarifying the provenance of birds (Table 4.1). Though there are some visual indications of captive breeding, such as leg rings (Chng et al. 2015), these are not reliable visual markers since wild birds can be laundered and mislabeled as captive-bred to evade detection by CLE (Shepherd et al. 2012). More accurate detection of wild birds would rely on complex lab-based processes such as stable isotope analysis that are not currently usable in the field (Haché et al. 2012; Andersson et al. 2021).

4.5.5. The role of technology in IWT prevention

Nonetheless, given the ultimate need to rely on verbal provision of a species identification in court in Indonesia (Table 4.1), and many other countries (United Nations Office on Drugs and Crime, 2022), a phone app for species identification could not replace human labour in the songbird IWT identification process. Rather, it can be a taxonomic aid to assist IWT detection and improve the monitoring of trade but not prosecution.

Technology can be used to help identify birds in the field and train staff. It can also be incorporated into existing CLE socialization processes, so they can tell traders with confidence that they are selling protected species, building cases against them and even confiscating birds. It could also be used to release birds properly based on their range data, but not as evidence to arrest or prosecute songbird IWT offenders. Similarly, the emerging use of police body cameras was introduced to protect civilians from violence by law enforcement. With IWT technologies, most are directed at law enforcement. Learning from body cameras, though they do not neutrally report interactions, with strict regulations on their use and access, they may make citizens less vulnerable and police more accountable (Houwing and Eck 2020).

There are still other changes that can be implemented to improve species identification in the field. One relevant practice we can learn from is how citizen science deals with imperfect taxonomic knowledge. Some systems assess the feasibility of submissions based on the location of the record; others send images to a set of expert "validators" (Iliff et al. 2020). What is lacking in the IWT case is the automation of that checking and the software that underpins it. For instance, informal methods like WhatsApp for species confirmations could be formalized and replaced with a report and validation service with a small number of trained experts as greater efforts to bring together taxonomic knowledge.

4.5.6. Future directions

A CP/PD methodology is not necessarily dependent on the technology reaching full implementation, and after conducting this research, we do not explicitly recommend the immediate release of a tool for bird species identification to Indonesian CLE in the current system. We remain cautious of the role of conservation technologies being co-opted for punitive law enforcement and share the concerns of CLE in terms of technology use impacting trade actors' livelihoods. Still, we provide valuable insights into the barriers, challenges, and potential future outcomes for songbird IWT in Indonesia if the design were implemented. These insights and outputs can be applied to other wicked problems in conservation, particularly that relate to CLE, enhancing their understanding of the realities of technology use in combating IWT.

Adopting a co-productivist-*with*-participatory design methodology would likely mean that fewer technologies are actually proposed and developed, though this would also lead to fewer failures (Loucks and Becker 2021). Given the funding challenges that CLE agencies are dealing with, technology companies could initiate longer-term collaborations to develop and host technologies if preliminary technology assessments indicate feasibility. These collaborations could be at scale (e.g. many companies funding assessments for many technologies that address a range of IWT issues) and involve working with conservation organizations and agencies over periods of at least 10 years. Consequently, equitable user-centered design processes rather than short-termist methods like hackathons and seed funding initiatives would be the first port of call. Ultimately, we see this work as an important contribution to wider conservation technology research, and we hope these methods can be used to explore other wicked problems in conservation through a preliminary technology assessment lens that shifts the needle away from the broader deterministic narratives.

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Reflections from a 'developer'

I couldn't do the research with a big team; technology development takes ages – I had to do the user research team of one method and rely on Helen Newing's[3] *and Leah Buley's books*[4] *To drag me through the work. Though I had field collaborators, we weren't a well-funded team, you know?*

Technology alone is not a solution to any conservation problem, but it may partly help overcome barriers such as species identification in the field. But still, I remain torn on the role of technology in IWT enforcement: if technology isn't accurate enough, am I just barking up the wrong tree? What is most at the forefront of my mind is the privacy concerns and the risks of using AI to place people under surveillance.

Vendors who are prosecuted and imprisoned aren't offered any rehabilitation and have few alternative options for income. Many of my FGD participants and interviewees feel that ending trade is not a realistic solution, but they want to find ways to make it more sustainable, with improved animal welfare. I'm included now in that group.

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[3] Newing, *Conducting Research in Conservation*.
[4] Buley, *The User Experience Team of One*.

Chapter 5. Rethinking extinction “crises”: The case of Asian songbird trade

5.1. Abstract

Different stakeholders and actors frequently describe environmental challenges as ‘crises’. These crises are often wicked problems that are difficult to resolve due to the complex and contradictory nature of the evidence and knowledge systems surrounding them. Here, we examine a crisis narrative surrounding the IUCN-declared Asian Songbird Crisis (ASC), with its epicentre in Indonesia, where an extensive birdkeeping culture persists. We investigate how bird extinction is perceived by different actors, particularly conservation law enforcement and practitioners working in this space. We unravel local perspectives on the complex relationship between bird trade and extinction through one-to-one interviews and focus groups. Our examination reveals a diversity of attitudes to the ASC, with many law enforcement actors not recognising the crisis label. Market mechanisms result in complex shifts in harvesting pressure onto one or more closely related similar species. The findings challenge the prevailing notion that species extinction significantly affects wildlife trades, emphasising the plastic nature of trade and the coming and going of species fashions. By revealing the divergent views of actors on extinction and the ASC, we highlight the need for shared language, particularly the implications of the ‘crisis’ label, around species extinction.

5.2. Introduction

5.2.1. Understanding crises

In environmental sciences, crisis theory refers to a framework that examines how ecosystems or species respond to external pressures. If many species face a high risk of extinction within a relatively short period, this response is known as an extinction crisis (Pimm et al., 2014). Biological extinction, in the simplest sense, is defined as the point at which the population of a species is zero. More complex concepts describe species that are unlikely to avoid extinction as ‘functionally extinct’ or, where a species persists only in captivity, as ‘extinct in the wild’ (Roberts et al., 2023). Anthropogenic extinction crises are often the subject of scholars and practitioners within the discipline of conservation, which Mitchell (2016) describes as the ‘systematic management of life forms to ensure their survival’. Conservation’s intimate relationship with extinction is worth considering given that conservation itself has often been described as a crisis-oriented discipline (Soulé, 1985), faced with problems that demand 'immediate action' (Mitchell, 2016).

Crises themselves are difficult to define and often fraught with contrasting definitions. One school of thought sees crises as discrete events, such as the 2004 Indian Ocean tsunami or Hurricane Katrina in 2005 (Paglia, 2015). These time-limited events could also be short periods of political upheaval or economic shocks, such as the 2008 financial crisis. Balestrini et al. (2020) understand crises as the critical moment of any process that has arrived at a 'decisive juncture'. Ecology does not refer explicitly to crises, but these 'decisive junctures' manifest during regime shifts as an ecosystem moves from one relatively stable state through a tipping point to another stable state from which it is difficult to return (Clements and Ozgul, 2018). These switches or oscillations are characterised by early warning signals as systems approach 'critical transitions' (Clements and Ozgul, 2018). These ecological early warning signals mirror the early warning phase defined in crisis management studies, which includes six phases that make up a crisis episode (Paglia, 2015).

Paglia (2015) and Kelz (2022) assert that crises at the forefront of conservation discourse, such as species extinction and climate change, cannot be 'proper' crises since they cannot be managed as discrete events where the status quo can be restored. Hence, dramatic ecological changes only become crises when we incorporate the broader sociopolitical implications of biodiversity loss rather than simply species decline and environmental change. For instance, marine fisheries experience population crashes or collapses but are only labelled as part of a "food crisis" when considering the anthropogenic causes and anthropocentric consequences. However, it is easy to see how such ecological transitions could become permanent, for instance, the transition from the past, where a species was alive, to a future in which it does not exist (Jørgensen, 2022).

In addition to the reversibility of critical transitions, their timescale is also debated. Although he calls it a crisis, in his work on defining and introducing the term 'Capitalocene', Moore (2017) argues that the origins of the ecological crisis are found in the British-led Industrial Revolution, which marks a longer period of socioenvironmental change rather than a more discrete juncture. Ferdinand (2022) goes further and argues for a much earlier colonial fracture, foundational to modernity and globalisation since the 1500s. Such a long-term, chronic view of crises is also suggested by Roitman (2013) when analysing the 2008 financial crisis. Thus, crises are not merely logical, ontological assessments of periods of change but can also be political denunciations of situations spanning long periods (Koselleck and Richter, 2006). Here, we consider what happens when this crisis label is applied to conservation challenges and how that label shapes knowledge and politics.

The framework of a conservation crisis can depoliticise inherently political situations by overly focusing on wildlife and their ecology. Conservation practitioners must act 'before knowing all the facts' (Soulé, 1985), often without valuable sociopolitical facts which provide the broader context of a putative crisis. Classical definitions of extinction do not account for nonbiological (for instance cultural) corollaries accompanying species loss. Conservation has long faced calls for greater recognition, participation and inclusion from the Global South, including indigenous perspectives (Masse et al., 2020). Conservation biology and the more humanities-focussed field of extinction studies prejudice the biological and assumed empirical permanence of extinction, a sterile understanding that extinction is something that 'happens' to nature (O'Key, 2023). Societies with more connections to nature, often that hold indigenous worldviews, understand a more mutualistic relationship between humans and nature, where extinction is a cultural or even sociopolitical problem. For example, indigenous groups like the Anishinaabeg people observe that animals actively withdraw from the world when societies break human-animal treaties (O'Key, 2023). This cultural appreciation for human-nature interactions is in opposition to forms of 'new conservation' (Büscher and Fletcher, 2020) that rely on neoliberal frameworks to understand nature and species' roles in ecosystems as ecosystem services that monetise both extinction and conservation (O'Key, 2023). Elsewhere, there are narratives of intrinsic trade-offs between conservation and the prevention of extinction and the economic development agendas pursued by national governments (Otero et al., 2020).

5.2.2. The Asian songbird crisis as a nested crisis

One example of a crisis narrative in conservation is the Asian Songbird Crisis (ASC). This crisis was labelled and declared by the International Union for the Conservation of Nature (IUCN) in 2017 in response to high rates of (il)legal bird trade across Southeast Asia (Shepherd and Cassey, 2017). According to the IUCN, this crisis declaration aims to prevent the 'imminent extinction of songbirds threatened by unsustainable trapping and the trade in wild-caught passerines' (Asian Songbird Trade Specialist Group, 2018). The declaration of this crisis was not triggered by the crossing of a particular tipping point but rather as the result of an ongoing process where 'the degree of pressure on songbirds in Asia is devastating and has long been grossly underestimated'(European Association of Zoos and Aquaria, 2023). A range of actors, largely in the Global North, such as zoos, universities and conservation organisations, have united for 'the common purpose of Asian songbird conservation'.

The global hotspot of bird trade is in Indonesia, where many practices involve birds for use as pets, food, prayer release or as omens (Gilbert et al., 2012; Su et al., 2014; Marshall et al., 2019). The wild bird trade in Southeast Asia, including Indonesia, is a somewhat atypical case study because illegal trade happens in the ’open’, where protected species are displayed openly in marketplaces or sold in violation of the national quota system (Shepherd et al., 2016; Shepherd and Leupen, 2021).

If we accept the ASC as a (singular) crisis, it is also nested within a larger global ecological crisis, forming a hierarchy of ‘nested crises’ (Kaukko et al., 2021). Some claim the legal and illegal trade in wildlife has created an ‘extinction market’, where species are traded until they become extinct (Felbab-Brown, 2017). The extent to which wildlife trade might drive a potential songbird extinction crisis is unclear, especially since many species threatened by trade face the synergistic threats of habitat fragmentation and climate change (Sagar et al., 2021). Hinsley et al.’s (2023) global review on wildlife trade-driven species extinction found 294 reports of ‘successful’ extinctions. Thirty-four reports related to wild birds, though not yet from the songbird trade (Hinsley et al., 2023).

Nonetheless, since its declaration in 2017, the ASC has arguably intensified as a ‘thing’ (pressure on birds) and a ’crisis’ (a discourse). Several species have been uplisted in conservation assessments by the IUCN, and 63 (sub)species are listed as conservation priorities by the IUCN Asian Songbird Trade Specialist Group (ASTSG, 2022). Conservationists, largely from Global North NGOs and universities, have dominated ASC discussions, framing this issue as a cultural and legal problem that stems from demands for birds and inefficient law enforcement. In contrast, in 2018 Indonesian birdkeepers lobbied to downlist popular species, such as the White-rumped Shama (*Copsychus malabaricus*) (locally extinct in most of its Indonesian range) (Gokkon, 2018b). The birdkeepers’ rationale was that these species were bred on a large scale and thus far from endangered, and their uplisting and effective banning would have uneven socioeconomic impacts across the songbird economy (Gokkon, 2018b). These conflicting views typify the tensions between groups of actors in the landscape of (conservation) crises.

To grasp the local implications of global or regional ’crises’, we explore the ASC in Indonesia as a case study of how crises manifest. Our goal is not to deny the severe impact of the bird trade on wild populations but rather to examine the implications and repercussions of declaring it a crisis. The ASC and its designated task force, the ASTSG, of which SF (the primary author) is a member, operate under the IUCN Species Survival Commission (SSC). Here, we explore how various local and international actors more embedded in power structures, such as conservationists, law enforcement and practitioners, perceive bird extinction within the ASC narrative.

5.3. Methods

We conducted field observations, semi-structured interviews and focus groups with law enforcement officers, conservation community members, environmental NGOs and academics primarily based in Indonesia. The questions asked during interviews and focus groups are part of wider discussions on the ASC (see Appendix C). Data collection took place in cities within Java (Jakarta, Bandung, Yogyakarta and Surabaya) and West Kalimantan (Pontianak), renowned for their role in the bird trade (Chng et al., 2015; Chng et al., 2016; Chng and Eaton, 2016; Rentschlar et al., 2018). Although Pontianak is not the largest urban market outside Java, recent research indicates it is an emerging bird source, with trade levels comparable to neighbouring islands (Rentschlar et al., 2018).

5.3.1. Field observations

We visited nine bird marketplaces (one in Bandung, Yogyakarta and Surabaya; three in Jakarta; and collections of shops in Pontianak) between January and June 2023. During each marketplace visit, we observed variations in the physical architecture of marketplaces, microscale dynamics between traders and buyers and aspects of the birds' health and welfare. Marketplace visits were approximately two hours long, with more time spent at larger marketplaces. All marketplaces were visited at least twice, apart from Jatinegara market in Jakarta, which was seen only once.

5.3.2. Interviews

We purposively selected participants engaged in bird trade issues from conservation organisations and universities in Indonesia and abroad. We conducted 16 semi-structured interviews in May and June 2023 (half in person and half conducted online via Zoom). Participants were asked about the consequences of species extinction on bird trade and birdkeeping practices.

5.3.3. Focus groups

We chose focus groups as they offer flexibility and openness, crucial for discussing sensitive topics (Newing et al., 2011, p. 54). Focus group discussions (57 participants in total, ranging between 8 – 13 per discussion) were conducted in the five cities, with focus group participants (FGPs) including representatives from agencies such as the Indonesian National Police (POLRI), the nature conservation agency (BKSDA), environmental law enforcement (GAKKUM) and agricultural quarantine. We obtained verbal permissions from agency heads through Yayasan Kausa Resiliensi, the local NGO with which we collaborated. These discussions explored whether law enforcement sees its job as preventing extinction (a more ultimate goal) than enforcing a law (a more proximate goal).

5.3.4. Data analysis

The data analysis followed a two-stage process. Initially, we conducted a discourse analysis to examine framings, narratives and language around songbird extinction. Subsequently, we performed thematic analysis, employing inductive coding following the method by Newing et al. (2011, p. 6), exploring themes around bird extinction, sustainable trade and their combined consequences, using grounded theory principles. Interviews were primarily conducted in English and later transcribed. Focus groups, conducted in Indonesian, were recorded and transcribed by student assistants and later translated using online tools and support from the research team.

5.3.5. Ethical considerations

Participants provided their free, prior, and informed consent (FPIC), and data from interviews and focus groups were anonymised (Ibbett and Brittain, 2020). Participants were identified by codes based on their international (I) or national status (L(ocal)), and sector (AC (ademic)), L(aw E(nforcement)), NG(O)). For instance, "AC_I_01" represents the initial participant in the international academic category, while all LE were local, so they are denoted as LE_01 and so on. Our methodologies received ethics committee approval from the University of Leeds (AREA FREC 2023-0419-521) and were conducted under a research permit (311/SIP/IV/FR/11/2022) from Indonesia's National Research and Innovation Agency.

5.4. Results and discussion

Below, we combine multiple lines of evidence drawn from interviews with NGOs and academics, focus groups with law enforcement professionals and visits to a wide range of bird marketplaces to extract four key themes concerning the ASC at a local scale in Indonesia. Firstly, we find that the 'crisis' framing of the ASC does not translate from the scale of global conservation to the day-to-day realities of conservation authorities on the ground. There are tensions between the absolutism of crisis and the complex and conflicting realities presented by local actors. Secondly, local actors see difficult links between species decline, extinction and the trade chain's responses. Thirdly, species extinction has limited economic consequences for the trade chain but may affect the ecosystems of harvested areas. Finally, we examine the perceptions of our informants towards birdkeepers and captive breeding as solutions to anticipated extinction.

5.4.1. Perceptions of crisis

Our data shows that Indonesian government agencies responsible for regulating the songbird trade often did not perceive there to be a crisis. In workshops, many participants asked us, 'What crisis?' This difference in perception of songbird conservation amongst law enforcement officials may be attributed to their focus on day-today operations and short-term, local trends. This viewpoint might also result from different education and training for law enforcement around the bird trade compared to conservation NGOs. For example, their work involves extensive protected species lists, '*in our area, there are around 500 protected animals [birds], and we do not remember all of them'* (LE_17).

Consumers and law enforcement alike may overlook the threat of extinction due to the widespread availability of at-risk species in marketplaces. For example, one interviewee remarked, *'If they do not have…any conservation background, nobody will suspect the White-rumped Shama will be protected because they are just so numerous in the market'* (NG_L_4). In Indonesia, the bird trade is a 'grey market,' where illegal items are passed off as legal (Dickinson, 2022). Species such as the White-rumped Shama (*Copsychus malabaricus*) (Figure 5.1) can be passed off as 'grey' if wild individuals are mislabelled as captive-bred and vice versa using the standard numbered rings used to track captive-bred birds. The fact that consumers encounter both wild and captive-bred birds in marketplaces contributes to distorted perceptions of extinction. Courchamp et al. (2018) showed that marketing charismatic species led people to believe these species are less endangered.

Figure 5.1: *The plate depicts a Javan Pied Starling (Gracupica jalla) (top left), Bali Myna, (Leucospar rothschildi) (top right), White-rumped Shama (Copsychus malabaricus) (bottom left), Lemon-bellied White-eye (Zosterops chloris) (bottom right). All photos by Sicily Fiennes.*

Materiality matters beyond a bird's source, as evidenced by uneven research attention and funding to high-profile, charismatic species such as tigers, elephants and rhinoceroses (Challender et al., 2014). Dickinson (2022) calls this 'fleshy geopolitics', where a wildlife product's fleshy material properties shape markets, regulatory systems and corruption. Bird trade is facilitated because birds are small and relatively easily transported, with one species fungible for another. As one participant phrased, '*more attention will be given to saving a single tiger than 1,500 songbirds that people do not even know their names and think there's already a lot in the market*' (AC_L_1), revealing a gap between conservationists' messages and local experiences.

5.4.2. Confirming extinctions

Our findings also reveal the challenges of declaring bird extinction that are shared by local actors and the international conservation movement. An example of the uncertainty over formal declarations of extinction is the case of the Javan Pied Starling (Figure 5.1) (Baveja et al., 2021), which has not been formally declared extinct by the conservation community but is recognised to be 'no longer really in the wild' (AC_I_1).

There needed to be more consensus on the extent to which bird trade can lead directly to extinctions. One interviewee emphasised the role of trade as *'the extinction driver in Asia right now',* commenting that *'I have seen a bunch of species get depleted in numbers: various bulbuls…hill mynas…most of them are going extinct because of the bird trade*' (AC_I_1). On the other hand, another interviewee commented that '*it is very difficult for things [birds] to become extinct*' (NG_I_2). In contrast, law enforcement hypothesised that '*for extinct species, the demand in the market will be higher…and the value of the birds will also increase*' (LE_14).

Others from NGOs did not support this interpretation of low substitutability. Several participants described how when one species declines, trappers *'[switch] to another species' (AC_I_1), seek another bird' (AC_L_2), or '[trappers] just substitute'* (NG_I_2). While the participants did not mention it explicitly, these comments resemble the process of 'substitution elasticity' (Fraser et al., 2023). Understanding how substitutions occur is critical when considering why so few extinctions have resulted from the songbird trade (Hinsley et al., 2023). Interviewees suggested that, at a certain point, the efforts of finding rarer species do not outweigh the benefits of substituting for another species. This shift may be of no consequence; '*I do not think anyone is that bothered if a species goes extinct. There will be another one that takes its place'* (NG_I_2). Substitutions can occur within a species complex, between species in the same genus, or based on shared traits within the same family. For example, some species have enough variation that they are split into several subspecies, like '*the White-rumped Shama, which is already very rare in Indonesia [at the subspecies level], but they import it from outside: Malaysia, Thailand, the Philippines'* (NG_L_6). Species in genera with cryptic diversity, where multiple species look very similar, are vulnerable to 'true' substitutions within the same genus. The White-eye genus (*Zosterops* spp.) is a common example; *'take the Sangkar White-eye* [*Zosterops melanurus*], *absolutely millions of them in trade, and then they become exceedingly difficult to find, and then all of a sudden, the market's flooded with Lemon-bellied White-eyes [Zosterops chloris]'* (NG_L_2). In some cases, trade pressure may be displaced to species within the same family with similar traits, such as colour, song and size. In the bulbul (Pycnonotidae) family, 'sound-alike species' are also at risk; with the *'Straw-headed bulbuls [Pycnonotus zeylanicus]… suddenly, they start using grey-cheeked bulbuls instead, which is the second-best choice if you are into bulbul songs, so [grey-cheeked bulbuls] become rarer in the field*' (AC_I_1).

Others assert that generally, demand is never species-specific, that it is '*for the traits, or the use of the species…[there] is always going to be something else filling it in*' (AC_L_1). This 'filling in' of species has been described as a continuous process of 'rolling local extinctions' (Jepson and Ladle, 2005; see also Jepson, 2010) or 'near extinctions' (Eaton et al., 2015), which drive species substitutions and an increase in trapping effort, even though *'there are still birds everywhere. People go further afield*' (NG_I_2). This process also has permanency; '*if we talk about Indonesia, the trade will never stop because the tendency of traders will not let trade disappear*' (NG_L_6).

5.4.3. Socioecological impacts of trade

A common theme when discussing the consequences of trade on the wider environment was the ecological and socioeconomic consequences of species loss. Broadly, indiscriminate and opportunistic trade can reduce the diversity of a species community, leading to a reduction in community function; '*it will be that the environment or ecosystem equilibrium is disturbed*' (AC_L_2). This idea was echoed in a focus group: '*the loss of one component of the ecosystem will disrupt the balance*' (LE_25).

Trade could disrupt ecosystem stability, for instance, '*food chains, pollination of seeds, and the fertilisation of the soil by droppings*' (LE_5). Particularly, *'[a bird's] specific function might be lost, for example, an insectivore, or nectarivore*' (AC_L_2). One FGP gave a specific example; *'[a decrease in] owls…would mean an increase in the population of rats and snakes*' (LE_29). Interviewees also linked ecosystem instability to the loss of habitat specialists and other indirect threats of deforestation; '*I think there will be many species that disappear… that are dependent on forests areas…the number of birds that you can harvest has decreased because there's no more habitat…they do not live in oil palm plantations and other agricultural areas*' (AC_I_1).

The literature would suggest that birds have important roles in community ecosystems. However, the recognition or understanding of these roles amongst trade actors is unknown, with one interviewee commenting that these roles are '*completely unknown and misunderstood by the [birdkeeping] community*' (NG_L_7). The ecological impacts that result from the loss of rare species, at present the concern of the ASC, are also unclear. Kleijn et al. (2015) argue that common species (particularly bees) handle most pollination tasks, making the loss of rare species less economically significant. Still, some rare species may have unique roles or indirect contributions within their ecosystems, and geographically restricted but locally abundant rare species can still provide valuable services (Dee et al., 2019).

Common species are also at risk, often sold in larger numbers and worse conditions due to their perceived low value and unprotected status. In a Jakarta bird marketplace, for instance, SF (first author) observed the live suffocation of several Scaly-breasted Munias (*Lonchura punctulata*), and a dead individual in a water pot. An interviewee was *'watching a cage full of munias being spray painted…*

in the first five minutes, 20% just dropped dead…I assumed from the digestion of the chemicals' (NG_I_2). A few interviewees also emphasised that '*harvesting unprotected species is still harmful*' (NG_L_7).

In Indonesia's songbird economy, the socioeconomic consequences of population crashes may 'affect people who rely on it for their livelihoods and jobs' (LE_41). Conversely, an NGO staff member suggested that population crashes will '*only really bother high-end traders…and those in the field trapping the birds…there are fewer things for them to trap and less money*' (NG_I_2). This may also privilege wealthier consumers: '*those who can own and sell birds [will be] people who can afford to pay a high price*' (LE_27).

In the long term, as rarer species decline, both the songbird economy and the composition of ecosystems in Indonesia may become dominated by resilient, common species. According to Hughes et al. (2022), there has already been a loss of morphological diversity among birds in East Asia. As stated by one interviewee, '*You might come to a point where we are going to have to live with the resilient birds*' (AC_L_1). While specific data on longer-term evolutionary consequences of harvesting on songbirds is lacking, research on bighorn sheep suggests that intense harvesting of certain traits has long-term consequences, for instance, decreased horn size in offspring (Rice et al., 2022).

5.4.4. Views on the role of breeders and breeding

In response to the problem of trade-induced declines, many interviewees added to the discourse on the role of birdkeepers in songbird conservation, birdkeepers' savourism towards wild bird populations, and the role of captive breeding in mitigating the effects of wild songbird harvest. Similarly, we consider perspectives on how the state (intervenors) perceive the people being intervened on (birdkeepers) through deploying the crisis narrative.

Participants described how birdkeepers perpetuate notions of saviourism, relating to heroism and resistance, where they prevent extinctions and alleviate marketplace conditions. This savourism directly opposes racialised stereotypes in earlier conservation commentaries, which describe aviculturists who demand rare birds as malevolent (or ignorant) (van Balen et al., 2000). In contradiction to these stereotypes, the heroic saviour says that '*by buying the birds, they are also saving them from extinction*' (NG_L_5). Breeders of rare birds may also believe that '*they are helping the government to conserve the birds*' (NG_L_5). Birdkeepers may also go '*to the market and see a certain animal in a condition they believe deserves to be helped…so a sense of compassion arises*' (NG_L_6).

Sections of the Indonesian government also conceptualise breeding as conservation. For instance, official governmental guidance states that registered breeding facilities can catch protected species in the wild and sell the offspring, then release 10 % of their captive-born stock back into the wild (Gokkon, 2018a). One FGP referenced this policy, stating that '*the government should prioritise captive breeding (for protected animals) or animal husbandry (for unprotected animals). Bird breeding in Indonesia is widespread, and 10% must be returned to nature'* (LE_5). This pro-breeding approach aligns with the current Indonesian President, Joko Widodo, who supports captive breeding (Cabinet Secretariat of the Republic of Indonesia, 2018; Nuruliawati, 2018). In 2018, at a singing competition held at his residence in the Bogor Botanical Garden, he stated that he saw captive breeding as a 'space for bird enthusiasts that can also prevent birds from extinction' (Cabinet Secretariat of the Republic of Indonesia, 2018).

In contrast, the resistant saviours see themselves in place of state-sponsored conservation. This attitude appears to be linked to a mistrust in the government, where '*keepers think that if they keep the birds, they are also conserving the birds from extinction because they think that our forests are getting lost'* (NG_L_5), and the perception that birds are safer in their care: '*birdkeepers think it is better to keep the bird in my cage, so I still enjoy the song and can see the birds'* (NG_L_5). This attitude shares similarities with civil society resistance observed in urban areas of the Global North, such as Northern Europe and eastern parts of the US, where citizens engage in acts like 'guerilla gardening' or 'citizen greening' in response to a perceived lack of environmental stewardship (Baudry, 2014). It is possible that some birdkeepers still want to avoid state and institutional involvement, and their individual breeding efforts can be conceptualised as guerilla conservation.

The extent to which captive breeding can be a conservation solution was debated; one interviewee suggested it '*is the only realistic solution at the minute'* (NG_I_1), whereas others were less positive. One participant expressed concern that '*there are not the breeding facilities to develop or elevate the number of the individuals of the species'* (AC_L_2) and '*there's not enough availability in the market. [Captive bred birds are] too expensive…beginners…they will start with a wild one because it is easy and cheap*' (AC_L_1). Further, some participants felt that the financial rewards of captive breeding of near-extinct species are prioritised over conservation gains: *'[many] people [try] to breed a species they like, such as the green leafbird…[they] might think, if a species is heading towards extinction when I succeed in breeding it, the price will also be high*' (NG_L_5).

5.4.5. Alternative framings to the ASC

Specific framings of trade-induced bird declines can drive responses and financial support. To illustrate, labelling the illegal hunting of elephants as a 'poaching crisis' led to strict, culturally specific responses, including shoot-to-kill policies against poachers in South African national parks (Lunstrum, 2014). Fletcher (2015) highlights the 'ecotourist gaze', representing a desire to connect with nature as an escape from industrial civilisation. Framing the Southeast Asian bird trade from outside of Indonesia, based on conservation ideologies, resembles Fletcher's ecotourist gaze. The crisis narrative itself relies on conservation mechanisms rather than the integration of birdkeepers and broader civil society. Thus, the ASC takes the 'conservationist gaze' by privileging wildlife conservation over the needs of humans who benefit from songbird trade or even trade actors worried about bird declines, exemplified by the Silent Forest Campaign (European Association of Zoos and Aquaria, 2023).

Reminiscent of Rachel Carson's 'Silent Spring' (Carson, 1962), a silent forest erases human inhabitants of forests and reifies colonial notions of 'untouched' nature (Ferdinand, 2022). The conservationist gaze focuses on rare species, making nonthreatened species the 'unloved subjects of extinction' (Mitchell, 2016). Similarly, the protected-unprotected binary reinforced by law enforcement prejudices commoner species. Framing a problem as a crisis attracts more funding, as powerful images inspire political mobilisation, and media visibility plays a crucial role in establishing crises (Väliverronen and Hellsten, 2002; Kelz, 2022). This is the case with the ASC, which post-declaration has received greater attention in academic research (Mirin and Klinck, 2021) and increased international funding for songbird conservation.

Roitman and others reveal that crisis narratives tend to advocate a return to a restricted status quo, hindering fundamental change. The use of crisis language narrows our focus, obscuring capitalist systems of oppression and exploitation (Khasnabish, 2014). It is important to acknowledge that the unsustainable harvest of songbirds is partly driven by rising unemployment and economic necessity (Lucas, 2011). Notably, law enforcement was concerned that 'Indonesia's economic needs are still very high. Birds have a significant market value' (LE_5). (Il)legal bird trade may continue due to unaddressed global structures of inequality that drive illegal wildlife trade (Duffy, 2022, p. 30).

As a conservation intervention, the ASC lacks support from Indonesian agencies and songbird trade participants, neglecting long-term strategies (Masse et al., 2020). Conservation interventions without complete stakeholder buy-in often fail (Cooney et al., 2021), and the declaration of the ASC may falter as the impact on wild bird populations worsens without necessary local adaptations that incorporate the lived experiences of actors such as trappers and hunters. In work on attitudes towards IWT, Arroyave et al. (2023) found that rural communities justified wildlife utilisation since they are deprived of other production means and wildlife is used to meet basic needs. Similarly, one participant mirrored this necessity '*whenever I go into really rural areas, like the West Sumatra islands, I find the local police to be completely unreceptive to any arguments of having to jail…or…apprehend someone who is involved in the bird trade…they will just let them do whatever they want to do, because these are just people following their livelihood, trying to make a living, trying to feed their families*' (AC_I_1).

In addition to our suggestion to broaden the range of actors engaged in songbird conservation, here we present an alternative, framing bird trade within an unsustainable trade narrative; 'The Asian Songbird Challenge'. Following Roitman, we do not suggest that there is a singular alternative to crisis-framed narratives (Khasnabish, 2014). However, this framing is based on the similarities between the bird trade and the fishing industry. Though overfishing and trapping wild birds in Southeast Asia do not perfectly equate, the rapid population declines leading to 'fishing down the food web' (Pauly and Palomares, 2005), quotas, and shifts in focus to cheaper species when stocks collapse are commonalities. Although ecosystem service narratives have been criticised as neoliberal (Silvertown, 2015), the emphasis by law enforcement on the functional roles of birds and the ecosystem-level impacts of bird trade may be a more useful message for communicating the challenges of songbird trade governance rather than through a conservation crisis. Our findings suggest, therefore, that a more effective and inclusive framing would weave together biodiversity and ecology with a greater focus on socioeconomic factors that are most relevant to local actors. Looking at environmental humanities scholarship, scholars such as Jørgensen (2022) argue that 'extinction [as a process] is not a linear phenomenon', offering a less final and more optimistic perspective, in contrast to the catastrophism that extinction crisis discourses offer. This challenge to the linearity of extinction is inspired by a diverse range of observations, including indigenous knowledge systems that consider extinction as a change in interspecific relationships rather than a final death biological extinction, the survival of biologically extinct species in cultural artefacts, the evolutionary regeneration of lost life forms, and the "rediscovery" of those species that were never really lost (for instance, species rediscovery rates are at an all-time high (Scheffers et al., 2011)). Likewise, the ASTSG acknowledges that 'the growing threat to an ever-increasing number of songbird species can be reversed'. One interviewee also highlighted the potential for this reversal and species recovery: '*I think many species are thriving better than we thought they were*' (AC_L_1). There are parallels with discussions on fisheries and population decline, where shifts are seen as crashes or collapses but not as complex, multidisciplinary crises or discussions on global extinction. This potential for reversal of trends for declining populations of songbirds is similar to ’recovering stocks’ when fishing pressure is reduced for commercially important species. Thus, reinterpreting extinction as Jørgensen does, by ‘anticipating extinction’ or allowing populations to recover, allows us to shift to more interdisciplinary and multifaceted understandings of species decline that are separate from traditional Western scholarship definitions.

5.5. Conclusions and recommendations

The crisis narrative obscures aspects of the Asian songbird trade, including state actors not recognising a crisis. Bird trade is a ‘daily wildlife trade’, particularly in Indonesia (Duffy, 2022, p. 35). Despite few official extinctions resulting from the ASC, the Southeast Asian bird trade challenges simplistic extinction narratives due to substitution elasticity and changing traded species. We recommend using the ‘Asian Songbird Challenge’ for a nuanced perspective, avoiding oft-hyperbolic language such as ‘crisis’ or ‘silent forest’. Drawing inspiration from overfishing narratives, we acknowledge the severity of wild bird extraction with a framing distinct from the conservationist’s gaze. While an analogy to the fishing industry is needed, wildlife trade research must improve upon the industry’s failures (Crona et al., 2019). We do not argue that a simple change of terminology will resolve the issue of a lack of agreement on the situation. However, framing songbird trade as a challenge with many components - singing contests, breeding programmes, sustainable harvesting - could weave together the cultural and ecological priorities of the different actors, as presented here. Building on earlier, unheeded calls from researchers such as Jepson (2010), we propose tangible cooperation among governments, conservation practitioners and birdkeepers, bridging gaps for sustainable futures. Beyond the Bali Myna’s success, more incentives must be given for breeder integration into conservation efforts. Dialogues are needed for sustainable bird trade, utilising knowledge and infrastructure from birdkeepers and conservation breeding centres (Marshall et al., 2019). Our findings aim to stimulate ongoing dialogues and promote captive breeding as a valid tool in songbird conservation.

5.6. References

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Ruminations on human-bird relations

Another chapter, another reflection, I still feel like I can't wrap my head around crisis narratives. Why does international conservation care so much about 'crises' in other places? To me, conservation's main problem with the wildlife trade is that it prefers animals to be alive in the wild, captive-bred in a cage or incinerated rather than released in the wrong location. As Chapter 5 highlights, the Silent Forest narrative reinforces idyllic notions of wilderness, mostly for the benefit of conservationists rather than the Indonesian people who live there[5]*.*

When I was having a well-needed break from fieldwork in Bali (lucky me), I was chatting with a couple of fellow travellers from the UK. I upset them with the contention that people care more about birds in trade because of its viscerality and envisaging a life of suffering for the bird in a cage, whereas no one bats an eyelid about millions of birds lost in the UK to domestic cat predation, bird strike, farmland encroachment of their habitat and the like. They protested but 'cats are carnivores', that's natural. A-ha I said, but they're not, they're invasive predators devastating certain ecosystems and if we cared about birdlife at all we'd at least equip them with bells or keep them inside. To which their protestation was, but that's not fair. This conversation showcases a lot about the cultural imagination around the cage and it's representation, usually in Western culture. Birds are oft seen as symbols of freedom, like Maya Angelou's 'I Know Why the Caged Bird Sings'.

Diametric to these sentiments, some harvesters, after one of my interviewees asked them why they hunt, protested in response, saying, 'It is not like we're killing them'. It is apparent that conservationists and birdkeepers value animal lives very differently.

[5] Fiennes et al., 'Rethinking Extinction "Crises"'.

Chapter 6. A more-than-human political ecology of Indonesian songbird trade

6.1. Abstract

Since its conception as a discipline, conservation has considered the 'problem' of wildlife trade. In focusing on conservation outcomes, we almost wholly omit discussions on the welfare of animals and plants, and the harms they endure. Here, we develop a political ecology approach that incorporates the interconnectedness of people with animals and natural habitats ("more-than-human") to study the Indonesian bird trade, which is deeply culturally embedded, monetised and speciose. Bringing together marketplace observations, 1-1 interviews with experts, and focus groups with law enforcement, we map out the trade across three levels (actor, inter-actor and market level) to explore flows of birds, interactions, and power dynamics within this economy. We use a method that considers both human and bird perspectives to recognize birds as active participants with their own experiences

Specifically, we acknowledge previously obscured harms experienced by birds like feather plucking, dismemberment, sinus infection, overcrowding, suffocation and death. Different forms of harm occur to birds in different parts of the supply chain and depend on the human actors with whom they are interacting. Loss of freedom occurs at harvest and physical/physiological harm during transit and at the point of trade. However, harms are lower for highly sought-after species, though they are difficult to source and are well cared for by affluent collectors, but harms are higher when demand is high, and supply-side factors lead to broad harvesting with lower consideration of welfare. Our findings also indicate that men of different classes engage with birds for various reasons, such as for socialisation, investment and connecting with Javan traditions. We use this interdisciplinary approach to highlight the harms birds experience during the wildlife trade, relating to the Five Domains welfare model. Critical to understanding the harms endured are issues surrounding class, gender and culture in Indonesia, and other IWT contexts.

6.2. Introduction

Global capitalism and international trade have formed flows of animals, plants and fungi (Hodgetts and Lorimer 2015), commonly referred to as legal and illegal wildlife trade (IWT) (Phelps et al. 2016). Some claim wildlife trade is an 'extinction market', where species are trafficked to extinction (Felbab-Brown 2017), though the extent to which wildlife trade drives extinctions is unclear, especially since many species face habitat fragmentation and climate change in synergy (Hinsley et al. 2023). As such wildlife trade is predominantly seen as the concern of conservation by policymakers, conservation organizations, and regulatory bodies (Duffy 2022). Wildlife trade has been justified on the basis that it can be legal, safe, sustainable, and traceable. Others argue against wildlife trade, based on its public health risks, such as zoonosis (Yang et al. 2020) and animal welfare concerns (Wyatt et al., 2021). IWT, a narrow set of activities in breach of national-level regulations (Duffy 2022, p.32), usually connotes trade in rare species or at unsustainable levels. However, IWT is not always detrimental to wild species and recent evidence suggests that legal trade can be just as harmful and unsustainable (Marshall et al. 2025).

Discussions about wildlife trade within conservation omit the materiality and experience of the individual entity that is trafficked, and how their life is transformed as they enter the wildlife trade circuit (Collard 2014). This omission is partly due to conservation's normative (e.g. ethical and moral) commitments to nonhuman animal populations and their habitats (Campbell 2012), and its imagination of animals as passive taxonomic objects. Affect for individual animals is often seen as the remit of animal welfare advocates and animal rights activists, though both conservation and animal rights movements have been critiqued for promoting unjust and uneven politics in the name of non-human lives (Oommen et al. 2019). Rather than recognising the trafficked animals as agents, both conservation and wildlife trade see animals as objects, properties and commodities rather than subjects, individuals and sentient beings, whether they are objects to be conserved or sold (Wyatt et al. 2022). Viewing wildlife as objects has three key limitations for a fuller understanding of wildlife trade: it ignores the social and cultural ideas that shape trades, it neglects how the material properties of the animals influence how trade happens, and it marginalises the welfare implications of trades.

The physical properties and behaviours of animals shape how they experience trade and harm but also shape markets in turn. For example, Dickinson (2022) shows how the fleshy material properties of caviar enable its laundering. Its chemical-isotope profile (over time the flesh of illegally laundered sturgeon can develop similar characteristics to that of captive-bred sturgeon) and composite form (caviar eggs are small and when thousands of legal and illegal eggs are mixed in tins it is impossible to verify their origin) contribute to its existence as a grey trade (Dickinson 2022).

The exploitation of less charismatic wildlife for food, pets, and for recreation is a major driver of wildlife harm (Hutchinson 2023). One complex case of wildlife harm is the caged bird trade in Indonesia, the global hotspot for bird trade. A segment of the market caters to Javan traditions that dictate men need various possessions to constitute a 'good life', one of which is a kukila (cockfight bird or songbird) (Yulindrasari 2017), though the practice is also influenced by royal nobility who used to display elite species outside their palaces (Pradita and Wardhana 2021). These regal practices formed the foundations for another subculture where birds represent status symbols.

Emerging out of these older practices and formally materializing in the 1970s (Mirin and Klinck 2021), singing competitions involve the training of various species of songbirds to sing and outcompete other birds. The commercialisation of singing competitions has meant that birds now provide important real and imagined animal capital (Hodgetts and Lorimer 2015), not just by elevating social status or engaging with Javanese traditions but also through instrumental and relational value (i.e. selling rare and expensive birds, selling competition winners and earnings from singing competitions). Birds' capital is intrinsically tied to their materiality; they are easy to transport and hide because of their small size (Maulany et al. 2021), and Indonesia's high avian diversity ensures that one species is fungible for another (Fiennes et al. 2024).

Pons-Hernandez (2024) argues that 'it is easier to exploit (trade, traffic, or eat) nonhuman animals if we do not see their suffering'. A harms-based and victim-centred approach to wildlife trade (Wyatt et al. 2022; Hutchinson 2023) can help us understand the scale and nature of animal suffering but also understand what these harms reveal about the underlying structural drivers of IWT (Duffy 2022). Multispecies ethnography (MSE) provides a tool by which to study the human and non-human actors in IWT while recognising animals as subjects, individuals and sentient beings (Wyatt et al. 2022). Multispecies ethnography has focused on the many individuals of one species; see Tomlinson (2020) on horses or mice, or Tsing (2015) on the matsutake mushroom. MSEs of live wild animals in the wildlife trade, however, are scarce.

Building on Oyanedel et al.'s (2024) formative framework for understanding wildlife markets as complex systems, this study incorporates birds as nonconsenting actors whose physical traits and behaviours shape their experiences of trade. While Collard (e.g. 2013, 2020) and Wyatt (2021) have explored animal welfare in wildlife trade, they do not use multispecies ethnography or focus on Southeast Asian markets. This article extends political ecology through a more-than-human lens

(Greenhough 2014; Lorimer and Hodgetts 2024), treating wildlife trade as a cultural phenomenon, influenced by social differences like gender (Margulies et al. 2023), class and race (Margulies et al. 2019) that shape harms committed to traded animals. Here, we explore the harm done to individual humans and non-humans within the wildlife trade and how this is shaped by human culture and the material properties of animals involved.

6.3. Methods

We draw from five months of fieldwork (January to June 2023) across Java (Jakarta, Bandung, Yogyakarta, and Surabaya) and West Kalimantan (Pontianak) in Indonesia. This fieldwork involved three methods to conduct a more-than-human political ecology of the Indonesian songbird trade: short multispecies ethnography at bird marketplaces, focus groups with conservation law enforcement officers, and interviews with conservation practitioners and veterinarians. These methods are informed by a more-than-human political ecology framework, which seeks to understand how power, harm, and agency are distributed across human and nonhuman actors in the wildlife trade.

6.3.1. Visiting wildlife marketplaces

We visited nine wildlife marketplaces across each of the five research locations, with each marketplace visited at least twice, except for one in Jakarta, which was visited once. There are inherent tensions between creating ethnographic accounts that are empirically thick and the consequences of making people and places less anonymous (Lyon and Back 2012). To remedy this tension, we do not refer to marketplaces by name, nor do we publish images where the marketplace could be identified.

We take inspiration from the traditions of sensory ethnography and short ethnography to conduct a short multispecies ethnography (MSE). Short-term ethnographies are a focused and time-efficient approach to classical ethnographic research using immersive and participatory methods to provide a deep understanding of places (Pink and Morgan 2013). We use sensory ethnography methods to get a better understanding of the experience of nonhuman animals (Tomlinson 2020). In our case, sensory elicitation served as a gateway to multispecies ethnography, by attuning us to the sensory worlds of birds and the limits of human perception. The Five Domains Model further supported this by offering a structured medium through which to approximate the birds' experiences of harm. We adopt a form of MSE that treats nonhuman animals as intersubjective, individual actors who experience pain and emotions (Tomlinson 2020). Building on ethnographic methods of 'hanging out', we employed 'hanging around the market' to absorb the sensory and architectural environment of the marketplace. By visually documenting trade, which can enhance understanding of social practices and experiences during a condensed research period (Pink and Morgan 2013), we provide evidence of harms (Pons-Hernandez 2024). When we refer to specific species, we follow the taxonomy listed in the BirdLife DataZone.

6.3.2. Focus groups, interviews and human consent

In each city, we held focus groups (n = 5) with Indonesian conservation law enforcement agencies (57 participants from these agencies took part, with 8 to 13 participants per session) to discuss their roles and challenges in enforcing songbird IWT across the supply chain. We collaborated with four agencies: BKSDA (nature conservation), BKP (animal quarantine), GAKKUM (wildlife law enforcement), and POLRES (regional police). These agencies are referred to with the abbreviations BKSDA, KAR (Karantina = Quarantine), GAKK and POL. We conducted sixteen semi-structured interviews (eight in person, eight online) with experts from conservation organizations (represented with NGO in participant codes) and universities (using ACA for academic in participant codes). Interviewee codes are followed by an L for local or an I for international. These interviews focused on bird trade as a system and interviewees were asked to provide feedback on a preliminary supply chain diagram. All participants were compensated at a standard hourly rate and gave their free, prior, and informed consent (FPIC).

We analyzed qualitative data from marketplace observations, focus group discussions, and interviews using NVivo 11. Focus groups were conducted in Indonesian, recorded, transcribed, and translated (see Appendix C Guide 1). Interviews were conducted either in English or Indonesian, transcribed and translated into English if needed (see Appendix C Guide 2).

6.3.3. Vignettes and welfare assessment

Birds cannot give their consent to being photographed and surveilled. By being a spectator we risk reinforcing anthropocentric hierarchies, as by observing animals we reinforce the separation between humans and animals that anthropocentricism is constructed on (Hooper et al. 2022). To navigate this, we use vignettes developed during interviews with veterinarians, to document not only welfare concerns but also to critique our own anthropomorphism. These vignettes allow for a reflective exploration of the implications of projecting human qualities onto non-human entities, and the difficulty and limits of accessing animal subjects' experiential worlds (Hodgetts and Lorimer 2015). As Tomlinson (2020) argues, being critically anthropomorphism opens a route toward more ethical and situated forms of multispecies ethnography.We discuss a series of images and videos that depict avian suffering in marketplaces with veterinarians and present them here as vignettes. Vignettes are useful since they describe information in context (Rizzolo 2021), and can be used to clarify judgements. We use these as a source of expert opinion and categorise the resultant harms according to the Five Domains model (Mellor et al. 2020). This model acknowledges that animals have psychological as well as physiological needs. Bartels et al. (2022) used an older version, the Five Freedoms, to assess the welfare of captive-bred birds at marketplaces in Germany (both models are compared in Table F1). We consider the Five Domains in the following ways:

1. Nutrition: differences in diet in the wild vs. in trade
2. Environment: contrasts between the natural habitat with the confined spaces
3. Health: any health impacts, potential injuries, and lack of medical care
4. Behaviour: examine stress behaviors or inability to exhibit natural behaviors in trade settings
5. Mental State: explore how changes in the first four domains affect the bird's mental well-being.

6.3.4. Assessing the Indonesian macroeconomic market driving unsustainable bird use

We structure the results of our more-than-human political ecology through the three levels of Oyanedel et al.'s (2024) framework; actor, inter-actor and market analysis. The multispecies ethnography and vignettes contribute to our understanding of birds, welfare issues and how birds are moved in supply chains. The interviews, together with the focus groups, allow us to assess power dynamics within humans and between humans and animals. In combination, these methods allow us to understand the harm to birds and people within this system, based on social framings like power. While our primary data comes from enforcement and conservation practitioners, we complement this with secondary sources to contextualize the roles of trade actors.

1. Songbird trade actor analysis

We identify human actors in the caged bird trade, including harvesters, intermediaries, vendors, and consumers, considering cultural dynamics. We corroborate actor roles with existing literature, noting the multitude of roles in IWT market chains (Phelps et al. 2016). Birds are established as non-human actors, detailing their transition from wild to commodity lives using the Five Domains model.

2. Inter-actor analysis: examination of interactions

We focus on the relationships and interactions between market actors (human and non-human), the structure of supply chains, and the methods used to harvest and transport free-living wild birds to caged environments.

3. Market level

Lastly, we consider broader market dynamics such as supply-demand interactions, legal, grey and illegal entanglements and broader human-bird relations in Indonesia. We visually summarise existing information on 1. How are human actors arranged and their relations?, 2. how sourcing pressure has been displaced from Java, the core hotspot of trade, to Sumatra and West Kalimantan and 3. the legal, grey and illegal entanglements that bring birds to marketplaces.

6.3.5. Ethics

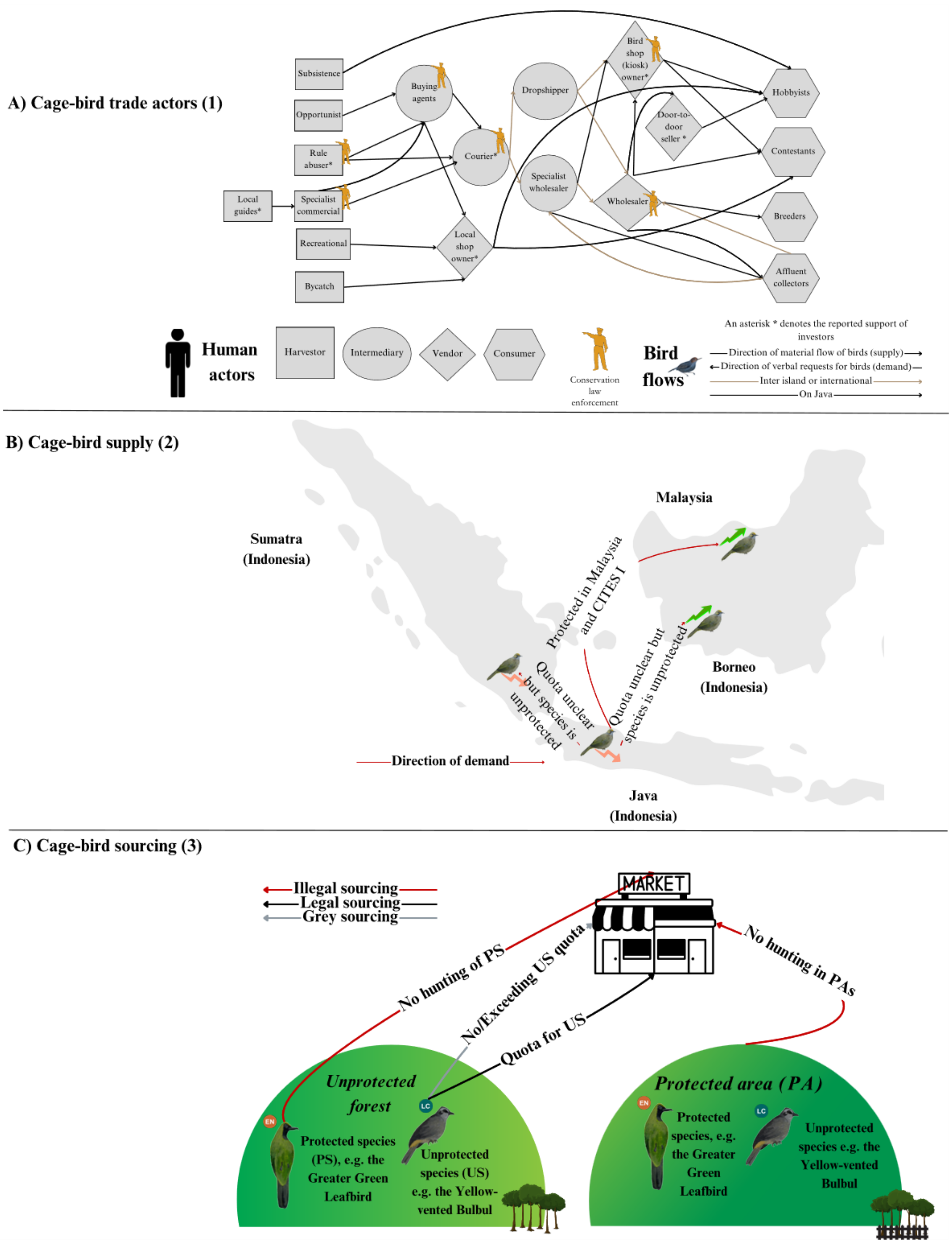
We received ethics approval from the University of Leeds (AREA FREC 2023-0419-521) and fieldwork was conducted under a research permit (311/SIP/IV/FR/11/2022) from Indonesia's National Research and Innovation Agency.

6.4. Results

6.4.1. Structure and organisation of the songbird trade network

The Indonesian songbird trade network mapped with study participants (Figure 6.1A-C) is consistent with the two parallel supply chains e proposed by Jepson et al. (2011): 1. local people and 2. syndicates taking birds from forests on a large scale, involving established business elites' (ACL1). These supply chains are not mutually exclusive. Whilst longer supply chains may be utilised more for high-volume and low-worth species, such as entry-level hobbyists and breeders, shorter, more direct supply chains are utilised for higher-end species (rare and/or expensive) (Figure 6.2A). The species composition in the former is more random, reflecting opportunistic harvesting, whereas the latter is more targeted and selective, particularly for specific consumer orders. There are some interactions and blurring between the supply chains, for instance, breeders who traditionally supply common species are now engaging in the trade of expensive and rare species.

Interview data suggest that over 80% of songbird trade in Indonesia is illegal (i.e. protected species, trapped in protected areas or exceeding quotas (Figure 1C) (NGOL7)). The trade is best characterised as decentralised and hybrid - partly opportunistic, and partly organised (Figure 1A-C). Therefore, the Indonesian wild bird trade is 'crime that is organised' rather than 'organised crime' (distinguished by Pires et al. (2016), when referring to wildlife crimes). As we explore in the following sections, this trade complexity plays out across the three analytical levels of Oyanedel et al.'s (2024) framework: the roles of actors, the interactions between them, and the broader market dynamics that shape harm to both birds and people.



A) Cage-bird trade actors (1)
Subsistence
Opportunist
Rule abuser*
Local guides*
Specialist commercial
Recreational
Bycatch
Buying agents
Courier*
Local shop owner*
Dropshipper
Specialist wholesaler
Bird shop (kiosk) owner*
Door-to-door seller *
Wholesaler
Hobbyists
Contestants
Breeders
Affluent collectors
Human actors
Harvestor
Intermediary
Vendor
Consumer
Conservation law enforcement
Bird flows
An asterisk * denotes the reported support of investors
Direction of material flow of birds (supply)
Direction of verbal requests for birds (demand)
Inter island or international
On Java
B) Cage-bird supply (2)
Malaysia
Sumatra (Indonesia)
Protected in Malaysia and CITES I
Quota unclear but species is unprotected
Quota unclear but species is unprotected
Borneo (Indonesia)
Direction of demand
Java (Indonesia)
C) Cage-bird sourcing (3)
Illegal sourcing
Legal sourcing
Grey sourcing
MARKET
No hunting of PS
No/Exceeding US quota
Quota for US
No hunting in PAs
Unprotected forest
Protected species (PS), e.g. the Greater Green Leafbird
Unprotected species (US) e.g. the Yellow-vented Bulbul
Protected area (PA)
Protected species, e.g. the Greater Green Leafbird
Unprotected species e.g. the Yellow-vented Bulbul
EN
LC
EN
LC

Figure 6.1: A): Actor map depicting the flow of birds through four stages: harvesters, intermediaries, vendors, and consumers. Quotes in Table F3 support the roles of each actor. B) Local extinction on Java and Sumatra drives inter-island (Kalimantan) and international trade (Malaysia), represented by the Straw-headed Bulbul (Pycnonotus zeylanicus), with range data based on Chiok et al. (2020). Birds drawn by Ishaan Patil. C) Pathways (legal, grey, illegal) for supplying birds from various sources (unprotected/protected areas) to markets, illustrating the structure and dynamics of the supply chain.

6.4.2. Actor-level analysis: characterization of bird trade actors

We identify the emergence of an undescribed user group, the affluent collector (Figure 6.1A, 6.2A). Existing consumer roles described by Phelps et al. (2016) are also evident also relate to the aesthetic and cultural values placed on songbirds by consumers because they are beautiful or seen as trophies (ornamental birds) or to fulfil deeply entrenched Javan cultural values (*manggung* or *merpati* competition birds). Other bird groups exist because of their market-based instrumental value with consumer cultures influenced by practices, noticeably *kicauan* and regal practices (expensive ornamental birds) (Figure 6.2B).

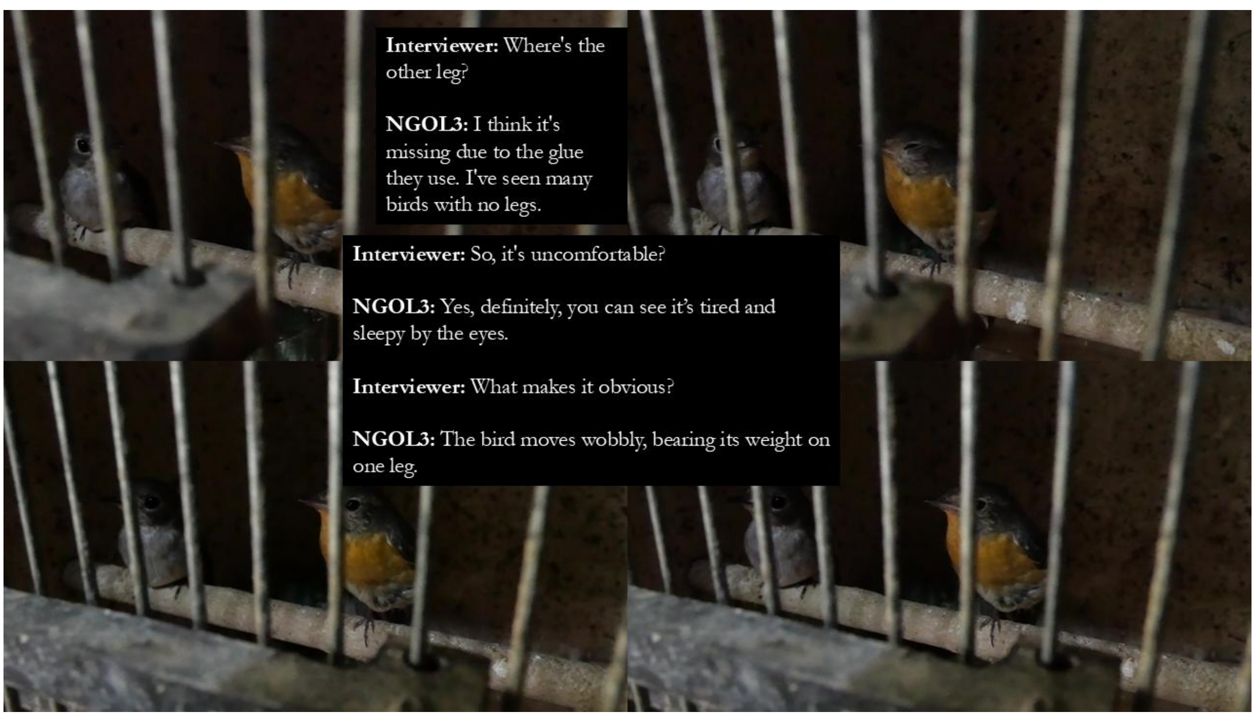
Figure 6.2: A) User groups in the Indonesian bird trade, including 1. Marshall et al.'s (2020) groups: hobbyist, contestant, and breeder, and our new category; affluent collector, 2. consumer uses from Phelps et al. (2016). B) Bird groups: house birds, master birds, competition birds and ornamental birds, overlap between human user groups with birds can be seen in the hybrid colours. Inspiration for some of the bird groups is taken from broader categories from Jepson et al. (2011) and Basuni and Setiyani (1989).

'*Apart from traditional [sabung ayam, manggung or merpati] or well-known good birds [high-end ornamental species like the Straw-headed Bulbul], trends are likely dictated by traders and availability [in the wild]*' (NGOI1). Previous studies (e.g. Marshall et al. (2020); Indraswari et al. (2024)) confirm that the contestant and breeder communities tend to focus on a relatively fixed suite of *kicauan* species that are eligible for singing competitions. A single consumer may own various bird profiles, from low-value ornamental birds for hobbyists to master and competition birds for contestants and high-value birds for affluent collectors. These profiles are not mutually exclusive, for example, one person's master bird may be another's ornamental bird (Figure 6.2B). A single consumer may own various bird profiles, from low-value ornamental birds for hobbyists to master and competition birds for contestants and high-value birds for affluent collectors. Bird profiles can overlap, as one person's master bird may be another's ornamental bird (Figure 6.2B).

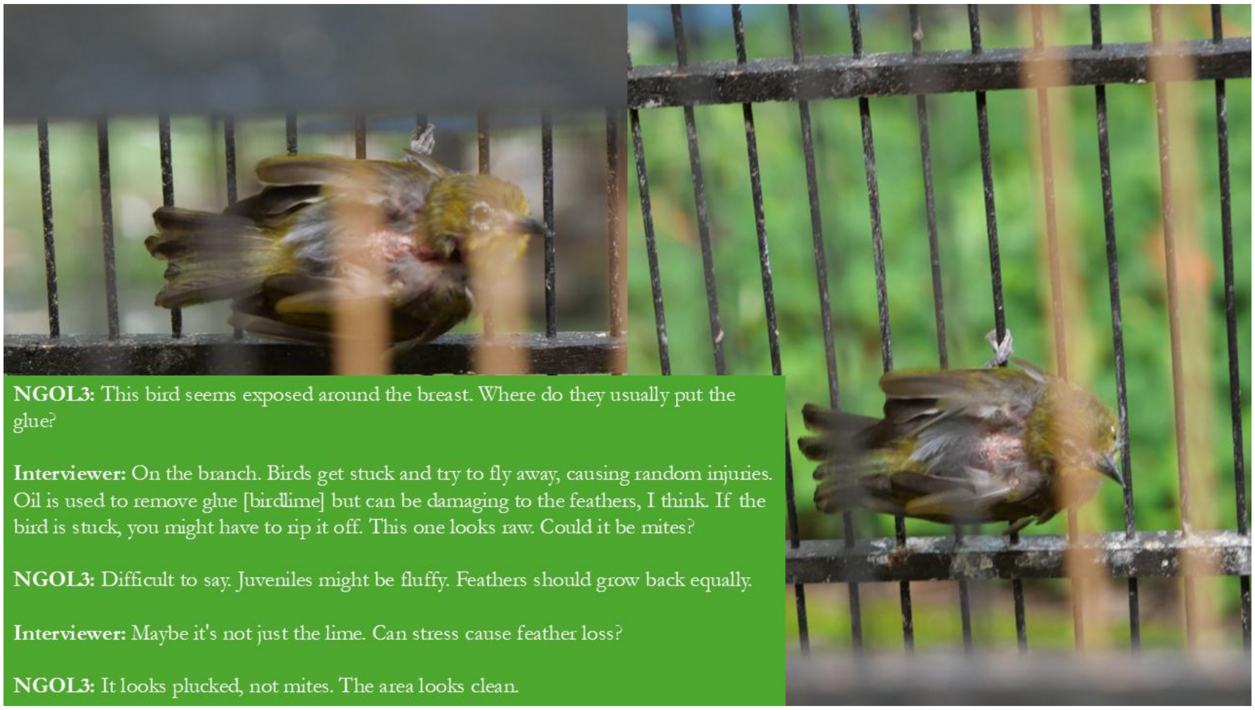
6.4.3. Vignettes with veterinary experts

Attending to the experiences of nonhuman animals is fundamentally a challenging task as '*wild animals have a masking phenomenon… They hide sickness to avoid predation'* (NGOL3). These vignettes highlight common misunderstandings around how animal harms are understood, particularly in the health, behaviour and mental states domains. In almost every instance, the initial interpretation of the authors was incorrect. For instance, the Sunda Scops-owl (*Otus lempiji*) (Vignette 4) most likely has a sinus infection, though it initially looked like a trauma wound.

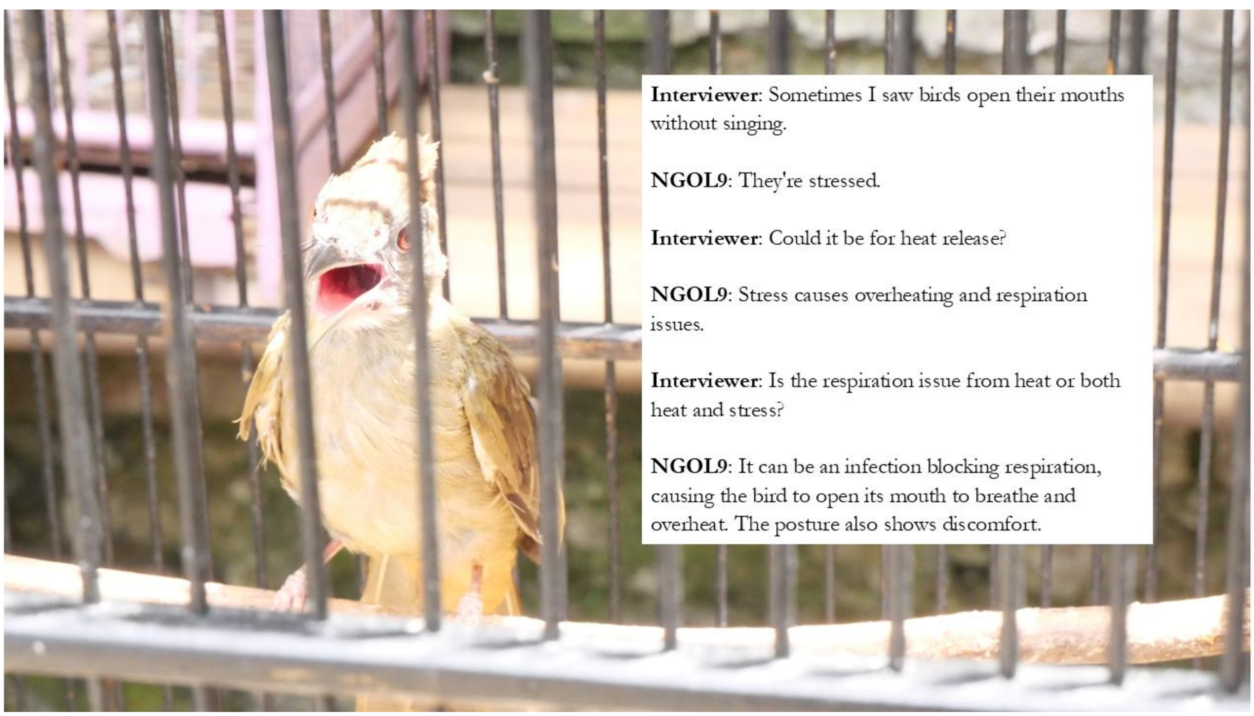
Vignette 1: Asian Brown Flycatcher (*Muscicapa latirostris*) (left) and a Mugimaki Flycatcher, (*Ficedula mugimaki*) (right).



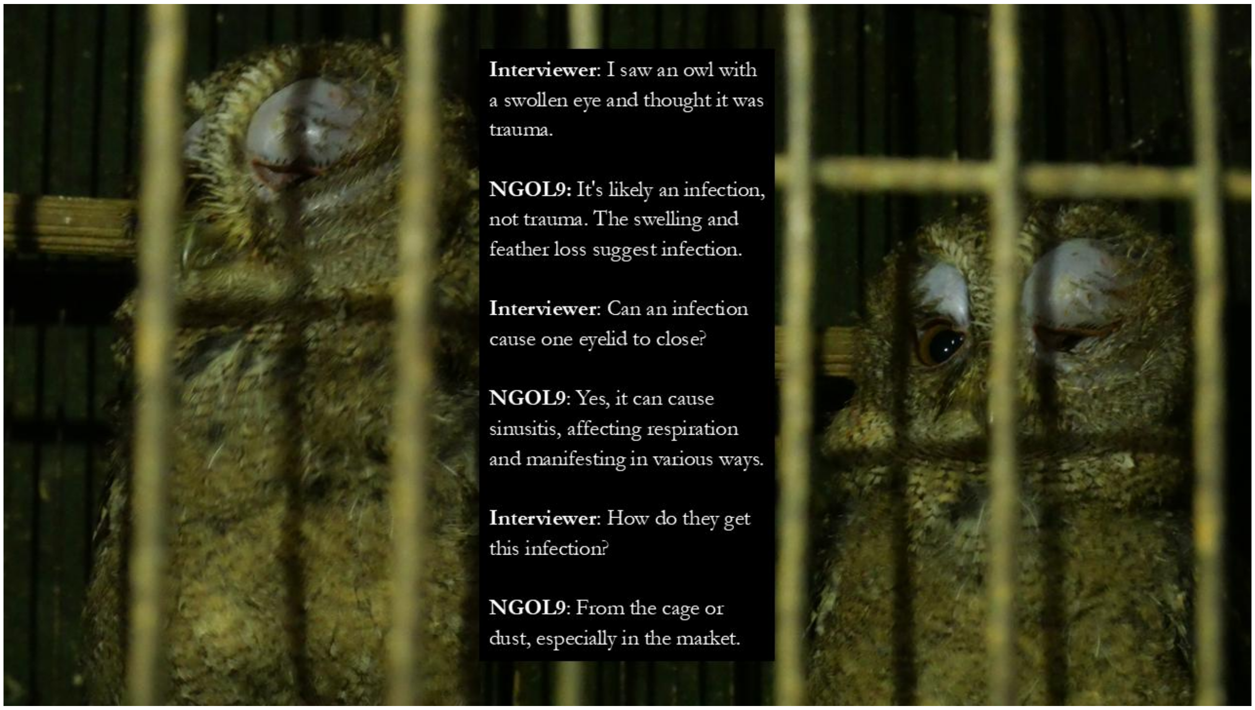
Vignette 2: A Hume's White-eye (*Zosterops auriventer*).



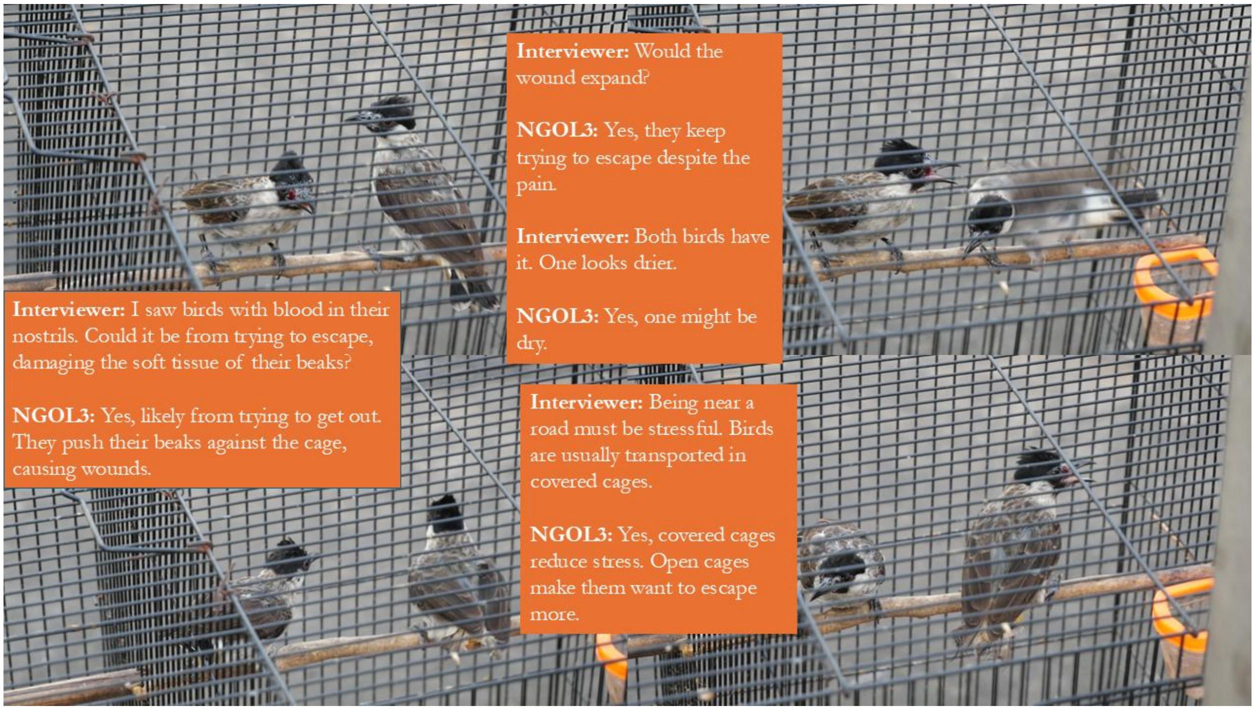
Vignette 3: An Ochraceous Bulbul (*Alophoixus ochraceus*).



Vignette 4: A Sunda Scops-owl (*Otus lempiji*).



Vignette 5: A pair of Sooty-headed Bulbuls (*Pycnonotus aurigaster*).



6.4.4. Five Domains: What is done to birds?

Even after taking a more critically anthropomorphic approach, it is evident that the fleshy properties of birds are changed, altered and removed in the marketplace (Table 6.1). In Table F2, we present the same information, along with additional violations noted in the literature and hypothesized differences between the wild and captive lives of birds.

Table 6.1: *Examples of violations of the Five Domains towards birds in trade, including from vignettes and other marketplace observations.*

Domain	Example
Environment	Overcrowding (Figure F1A)
	Birds covered in/ in close proximity in excrement (Figure F1C)
	Cages left in direct sunlight (Vignette 3)
Health	Broken limbs and damaged feathers (Vignette 1) can result from birdlime use
	Infections (sinusitis) from dust in the marketplace sinusitis (Vignettes 3 and 4).
Behavior	Being active, trying to fly away or escape (Vignettes 3 and 5)
	Plucking feathers on their back from stress (Vignette 2)

6.4.4. Inter-actor analysis

6.4.4.1. Supply chain structure: cooperation, ordering and financing

Interactions between actors in the trade network are shaped by both informal cooperation and hierarchical financing structures. Demand from consumers does not always drive supply. If a vendor receives a request in-person or an order, they may cooperate with other vendors: 'If his shop sells out of White-rumped Shamas and I have some, I can sell them to him' (NGOL8). However, interviewees also noted that more influential actors such as wholesalers finance smaller-scale vendors like kiosk owners or door-to-door sellers, as well as external investors (denoted with an * in Figure 6.1A). These financial relationships can limit the autonomy of some vendors, who consequently may have little control over their supply.

Given there has been a massive and difficult-to-quantify drain on Java's wild bird populations, most trade may now be inter-island (Figure 6.1C), made possible through the use of passenger ships (ACL1, GAKK_6, GAKK_9). '*[For orders] they use private vehicles'* (NGOL8, GAKK_8, GAKK_9), '*to reduce deaths. Deaths mean losses'* (NGOL6).

For the supply of expensive ornamental birds like *'parrots… [they use] navy vessels or special aeroplanes'* (GAKK_8) and the modus operandi can be tailored to evade detection by authorities, such as exchanging birds at sea (GAKK_8, BKSDA_17) or going through non-public ports (GAKK_9). The quality and condition of birds in the marketplace depends on how far away the bird is sourced; for the main inter-island trade routes (i.e. South Sumatra to northern Java and West Kalimantan to East Java, via Madura (GAKK_8, GAKK_9)), the journey could be half a day or several days if birds come from further afield (e.g. Papua (Figure F2)). Interactions between actors in the trade network are shaped by both informal cooperation and hierarchical financing structures. Demand from consumers does not always drive supply. If a vendor receives a request in-person or an order, they may cooperate with other vendors: 'If his shop sells out of White-rumped Shamas and I have some, I can sell them to him' (NGOL8). However, interviewees also noted that more influential actors such as wholesalers finance smaller-scale vendors like kiosk owners or door-to-door sellers, as well as external investors (denoted with an * in Figure 1A). These financial relationships can limit the autonomy of some vendors, who consequently may have little control over their supply.

6.4.4.2. Sourcing the supply: methods for harvesting and moving birds

Bird harvesting draws on knowledge of avian culture to adapt methods to bird behaviour (Lappe-Osthege and Duffy 2024). In the Indonesian songbird trade, this can be seen in the use of playback on speakers to lure birds using decoy birds, capitalising on male-male competition or relying on intricate methods derived from other artisanal practices like fishing (Figure 6.3, Table F4). How birds are trapped is also linked to the resources available to the trapper: '*bird lime is traditional and cheap'*, whereas '*mist nets are quite expensive, costing around USD* 50' (NGOI2). Birdlime has higher mortality rates, and birds sell for less (NGOL7), and as we have shown (Vignette 1), it can lead to dismemberment.

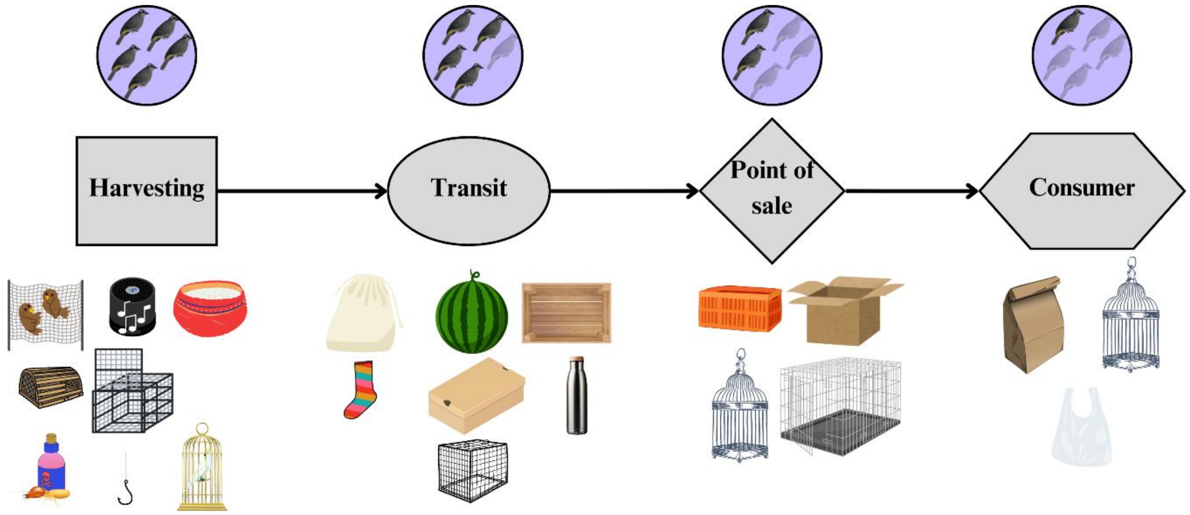


***Figure 6.3**: Summary of methods for harvesting and transporting birds for the live pet trade in Indonesia. Peng and Broom report a 90% mortality rate for small birds captured for pets. With 1 million birds trapped annually, 233,333 survive to be sold, indicating a 77% mortality rate. This hypothesis is based on incomplete data for small-bodied, sensitive species. Shepherd et al. (2004) found a 50% mortality rate for munias in the first 24 hours after capture. Confiscation data shows a 33% mortality rate during transit (Ramani and Clark-Shen 2019). Marketplace conditions further reduce survival rates. Approximately 1 in 4.35 birds harvested will survive. Starting with 5 birds, 1 will survive to reach the consumer.*

6.4.5. Assessment of market dynamics: Human-bird relations in marketplaces

Though mortality rates may be high across the supply chain (Figure 6.3), these, along with welfare standards, are dependent on the bird group. Extensive welfare violations and higher mortality rates are seen for small-bodied species like the munias (Table 6.1, Figure F1B/D), from the casual bird and cheap ornamental bird groups (Figure 6.2B).

Gendered social dynamics also shape birdkeeping in Indonesia. Marketplace observations suggest birdkeeping is a predominantly masculine pastime, with traders and consumers mostly male. There are various techniques used to advertise birds to male consumers, usually for low-cost species, for example in cages branded with international football team logos; with traders using playful branding e.g. calling a red Crimson Sunbird, Aethopyga siparaja as the 'Arsenal bird' (Figure C4). Other casual birds are spray-painted to be marketable to children (Figure C1 E). These techniques may help to sell 'new and unknown species by making them more appealing and exotic' (NGOL4), but for poorer vendors, there is a trade-off between keeping inexpensive birds alive versus letting them die.

Shops specialising in expensive ornamental species (e.g. rare native species like the Straw-headed Bulbul (*Pycnonotus zeylanicus*), or prized songbirds from China like the Black-throated Laughingthrush (*Garrulax chinensis*) and Hwameis (*Garrulax canorus*)) and popular *kicauan* competition birds (White-rumped Shama (*Copsychus malabaricus*), Oriental Magpie-Robin (*Copsychus saularis*), and the Orange-headed Thrush (*Geokichla citrina*) were much cleaner. Birds from these groups were sold in larger, excrement-free cages with varied food, and customers were asked to remove their shoes before entering the shop. '*High-priced, legally risky, or difficult-to-care-for birds tend to stay longer'* (NGOL6), but that is also because the vendor can afford to look after those birds.

Poorer consumers have fewer resources available for multispecies care (Bubandt 2024) and are unable to provide their birds with the best husbandry. Despite financial limitations, birdkeepers create home remedies based on community knowledge, often avoiding veterinary visits (NGOL4) and *'since COVID, there has been a rise in people building larger aviaries, allowing birds to spread their wings and fly, which is a significant improvement'* (NGOI1). Further, vendors can still sell sick birds, and the price may be related to how well the species survive. This provides additional clarity on the "cut flower" phenomenon noted amongst low-level hobbyist consumers (e.g. bird mortality is highest amongst hobbyists (Marshall et al. 2020). It might not be that they have the poorest level of husbandry but that they are buying cheap birds that are either sick already or sensitive to the conditions along the supply chain.

6.5. Discussion

We reveal that the Indonesian songbird trade is highly complex, informal and comprised of several overlapping pathways of supply. We detail harms to birds including infection, dismemberment and stress behaviours. However, these harms are mediated by the social differences of human actors (we explore those of vendors and consumers here), as well as the bird group. Multiple perspectives and value systems are inherent to wicked problems and IWT. It is likely extremely difficult to change how wildlife is valued and it is evident that songbird trade and associated harms to birds would vary if these cultural aspects were different. We contextualise our findings within the literature on other wildlife trade and small-scale economies and reflect on the questions of power (class relations, labour precarity, etc) that explicitly dictate the harms birds face.

6.5.1. Cooperation, investment and power

It has been suggested that most wild bird harvest in developing countries is a "cottage industry" (i.e. production in the home) (European Food Safety Authority 2006). Here, we show that wild bird harvest is not a cottage industry but a series of micro-enterprises that form artisanal clusters, catering to low-income consumers, where the role of intermediaries and vendors is dominant (Tambunan

2005). The growth of the Indonesian songbird trade is constrained by the reliance of poorer actors on powerful vendors such as traders, through informal and unequal financial relations.

The poorest human actors in the trade are likely to be harvesters. This was suggested by several interviewees and collaborators and is supported by earlier work on bird harvesting for food markets, where harvesters in Java and Sumatra) were reported to borrow from local wholesalers to support hunting activities (McCarthy and Noor 1996), which creates financial dependency. There is precarity from economic instability but also from physical risks to actors who provide labour at the site of production for birds (i.e. the forest). Diminishing bird populations drive harvesters deeper into forest interiors, sometimes involving walking more than three hours on foot to camp for several days and carrying birds back (Lucas 2011). The increase in illegal logging and agricultural encroachment in Sumatra and Kalimantan created new sources for wild-caught birds (Jepson et al. 2011) but also puts harvesters at risk of encountering snakes, tigers and bears (Silalahi 2020). This precarity is also seen in Romania's timber trade (Iordăchescu and Vasile 2023) where there is a class of precarious forest workers and petty woodcutters.

Turnover is not always high for rare species, and vendors are absorbing the costs of keeping animals alive as well as competing with online sources like dropshippers (someone who takes customer orders and forwards them to a supplier, typically through an online store) (Figure 6.1A). In surveys with bird traders across West Kalimantan, Miller et al. (2019) found that for 40% of bird shop owners, it was not their sole income source, nor was it particularly lucrative. Evers and Mehmet (1994) surveyed small-scale agricultural traders in Java, finding that nearly half borrowed money for business, mainly from informal sources like moneylenders. Wholesalers (traders) and dropshippers are likely to be financially independent and able to offer ordering options to wealthier consumers (Figure 6.2A). Black-winged Myna (*Acridotheres melanopterus*), that were stolen from a conservation breeding centre in West Java, were all sold at bird markets in Jakarta the next day, which indicated that the birds were pre-ordered (Sozer and Tritto 2014).

6.5.2. Songbird human actors: understanding the intersections of gender and class

The structure of bird trade reflects the broader informality of Indonesia's economy (Hao and Freischlad 2022), though as Thomsen et al. (2024) notes, birds and other wildlife are reduced to objects in part by the prevailing neocolonial capitalist framework, where developing nations like Indonesia are left little option but to exploit their own natural resources to partake in global markets. We advance understanding of the gendered consumption of birds (Miller et al. 2019; Bubandt 2024), showing that the class of the consumer relates to how birds are treated (i.e. their welfare), as well as how consumers interact with other trade actors.

Marketplaces are more than just transactional sites; they are cultural environments used as social spaces by trade actors, particularly hobbyists, contestants, door-to-door sellers and bird kiosk owners. Alcano (2016) observed the importance of street-side male socialisation and aggregation in low-income neighbourhoods in Surabaya, East Java, around activities like pigeon racing and gambling.

Bubandt (2024) suggests that songbird keeping evokes nostalgia for village life, fostering male companionship. However, we also highlight the coming together of modern hobbies like football fandom (Figure F4) with bird trade, reflecting contemporary social bonds between men. There are parallels between birdkeeping (kicau mania) and Indonesian football culture (bola mania) (Maulida 2024) that both involve ritualised, male-dominated activities, showing the global and modern aspects of these traditional social spaces.

Gender (specifically cisgender men) plays a significant role in other trades, like cacti and succulent trade, and aphrodisiac trades (e.g., rhino horn or sea turtle eggs). In cacti and succulent IWT, Margulies et al. (2023) hypothesise that men may be driven by heteromasculine notions of being daring. Conversely, Bubandt (2024) suggested that men see songbird competitions as safer than illegal activities like cockfights, even if the competition birds are illegally sourced. Marshall et al. (2021) reported a minimal fear of prosecution relating to songbird keeping amongst Javan consumers. Our results suggest that certain groups of birds are important as a medium of socialisation, something Sánchez-Mercado et al. (2020) noted in the international red siskin bird trade, where breeders, mainly middle-aged men, sought peer recognition most of all.

Our findings also indicate that men of different classes engage with birds for other reasons, such as for investment and connecting with Javan traditions. Poorer contestants (Figure 6.2A) may view *kicauan* competition or ornamental birds (Figure 6.2B) as an investment, as a means of class mobility (Lowen 2016). The urban middle class may aspire to be Javanese princes, and expensive ornamental birds once favoured by princes form part of that imaginary (Bubandt 2024). Affluent collectors can reinforce their social status by amassing diverse menageries of species.

6.5.3. Multispecies structural violence of the cage-bird trade

Relationships between human actors and the value of the bird aside, there is still structural violence embedded in the cage-bird trade. We document several methods of trapping and moving birds

(Figure 6.3) of varying degrees of cruelty, ranging from the use of fishhooks, termites impregnated with poison, and watermelons for transporting birds. These methods bear heavy similarity to fishing and hunting birds for meat. In Indonesia, Jepson et al. (2001) noted that Tanimbar Corellas (*Cacatua goffiniana*), were snared with nooses made from nylon fishing lines. Birdlime is used in the European songbird meat trade (Lappe-Osthege and Duffy 2024) and elsewhere in Southeast Asia, such as Myanmar (Platt et al. 2012).

Birds' behavior influences their trade experiences. Prey species, like songbirds, hide their pain (Doneley 2011). This is a critical factor in understanding why their exploitation is normalised, with minimal recognition of individual harms, which Hutchinson (2023) also observed in the European songbird meat trade. In the case of slaughterhouses, Hodgetts and Lorimer (2020) argue that the architecture and carcerality of the cage disrupt an animal's ability to express their subjectivities and thus human efforts to understand them.

Though birds' properties limit our ability to 'think like a bird' in complex and noisy marketplaces, a visual inspection is often all that is possible to document the harm towards birds. This approach was also fruitful for Pons-Hernandez (2024), who, in a series of photographs, revealed new and unexplored harms in another high-volume animal trade, the European eel trade (*Anguilla anguilla*). These included drawing attention to the risks of eels suffocating through means of transport like plastic bags and providing evidence of anxiety through the secretion of ammonia bubbles by stressed individuals. Though the study of bird behaviour is at least partially knowable through visual means, the Five Domains model is not suitable for all animal taxa, like reptiles, for whom welfare indicators are difficult to gauge (Baker et al. 2013). Nor is it an option for understanding the materiality of plants or retrospectively, post-mortem, to infer how an organism lived. We know less about welfare conditions in personal ownership of birds, though Collard and Dempsey (2013) note that once in a new home, the animals' lives are a shadow of their previous existence in the wild.

6.5.4. Socioecological harm reduction interventions

We recognize that wildlife trade is diverse and context-specific, encompassing legal, illegal, sustainable, and unsustainable practices (Hughes et al. 2023; Marshall et al. 2025). While some forms may mitigate harm, the label IWT often centers on legality rather than representing the actual impacts on individuals, species, or ecosystems. Our framework instead emphasizes harm as a more meaningful lens, acknowledging that IWT is a socially embedded phenomenon shaped by cultural, historical, and structural factors (Margulies et al. 2023).

Given the high social acceptability of the songbird trade (Marshall et al. 2020; Fiennes et al. 2024) eradication-based approaches are unlikely to be effective. Instead, we propose a socioecological harm reduction framework, a series of interventions that aim to reduce harm to birds while respecting the livelihoods and cultural practices of human actors involved.

As Termeer et al. (2019) argue, wicked problems like the songbird trade require partial, adaptive solutions rather than singular fixes. Building on Hübschle and Margulies (2024), we propose a series of socioecological harm reduction approaches to songbird IWT that focus on reducing harm to birds without compromising livelihoods along the four stages of the supply chain identified in our results: harvesters, intermediaries, vendors and consumers (Figure 6.1A). To us, "safe trade" is trade that actively acknowledges and reduces the individual harms birds face, such as stress, injury, and mortality, through less destructive harvesting, improved transport, and enhanced welfare standards.

1. **Harvesting**

As our results show, bird harvesting is often carried out by low-income actors with limited access to resources or training, which can mean they rely on more harmful harvesting methods. To reduce harm at this stage, the following incentives could be considered:

- Identify and protect species with high sensitivity to capture and captivity, using physiological indicators such as corticosterone spikes (e.g., corticosterone spikes (Cockrem 2007)).
- Trial payment schemes to incentivize the release of rarer or more vulnerable species, as seen in Indonesian shark and manta ray fisheries (Booth et al. 2023)).
- Phase out birdlimes due to damage to flight feathers (Platt et al. 2012), which reduces
- Promote peer-peer training from expert mist-net trappers and fund less lethal hunting methods like mist- nets, for poorer harvesters

2. **Transit**

The transport stage is a critical point of vulnerability for birds, particularly for small-bodied insectivorous species that dominate the Indonesian bird trade (Fiennes et al. forthcoming). Mortality during transit is often high due to overcrowding, stress, and inadequate conditions. To reduce harm during this stage, we propose the following interventions:

- Improve transport conditions, for example, Bocetti (1994) found that a quiet, dark environment with food, water, and minimal handling increases survival during transport for a Noth American insectivorous songbird. . These principles could be adapted for Indonesian contexts, particularly for long-distance inter-island transport and when birds are transported in some of the unconventional vessels we report here, e.g. socks, bottles and watermelons.

- Minimise overcrowding in transport vehicles (European Food Safety Authority 2006), as well as understanding species-specific densities for popular birds
- Transport birds in their normal social groups (European Food Safety Authority 2006), where possible.

3. Point of Sale

Our findings show that the bird's condition at the point of sale vary significantly depending on the type of bird and the socioeconomic status of the vendor. As such we suggest the following harm reduction interventions. These suggestions also reflect the reality that vendors who can afford to care for birds better tend to do so, suggesting that improving conditions is not only possible but already practiced in parts of the trade.

- Model conditions for expensive birds across all marketplaces: clean shops, spacious cages, food, and water.
- Install barriers between birds and visitors (Bartels et al. 2022).
- Avoid stacking cages and overcrowding, which exacerbate injury and disease transmission (Bartels et al. 2022).

4. Ownership

These interventions reflect the diversity of birdkeeping practices and the importance of working with, rather than against, existing knowledge systems. Bird ownership practices vary widely, shaped by socioeconomic status, cultural norms, and access to resources.

- Understand folk medicine practices by birdkeepers to promote avian longevity.
- Engage with aviculture communities and those interested in DIY aviary building to communicate welfare models like the five domains.

These recommendations are not prescriptive but offer a flexible framework for harm reduction that local communities can adapt to. Ultimately, the contours of any intervention must be co-developed with those most affected, ensuring that both human and non-human needs are addressed in tandem

(Green 2025). To advance a more inclusive and ethical approach to wildlife trade research and policy, we recommend adopting a more-than-human political ecology perspective. This framework emphasizes the agency, welfare, and lived experiences of non-human animals alongside human stakeholders. Key recommendations include:

1. Recognize individual animals as stakeholders in policy and practice.

This involves incorporating frameworks like the Five Domains to assess welfare and extending multispecies justice to include animals in legality, transportation, and captivity decisions. It also means attending to animals' materiality and behaviours, physical traits and actions, which shape how they are captured, valued, and traded. Understanding these dynamics is essential for designing interventions that reduce harm and respect animals lived experiences.

2. Integrate local knowledge and socio-ecological complexity into wildlife trade governance.

Engage with local knowledge systems, such as folk medicine and avicultural practices, to better understand human-animal relationships. Extend and adapt Oyanedel's (2024) framework to analyse how market structures, demand chains, and regulatory environments contribute to harm, not only to human communities but also to individual animals, which would allow us to fully capture the full socio-economic and ecological complexity of wildlife trade.

6.5.5. Concluding remarks

To conclude, there are various structures of power (framed by economic and class issues) that impose violence on birds but also human actors to varying extents, such as those who rely on external investment or are tied to the patronage of more powerful actors. Here, we recognise and explore the importance of birds as mediums for socialisation and income and as status symbols for a range of men from different socioeconomic backgrounds in Indonesia.

By recognising songbirds as individual victims we have provided a more detailed understanding of the harms birds face in trade. Shifts towards the more sustainable use of birds (i.e. using less destructive harvesting and transport methods and at a rate that does not lead to long-term decline) can also reduce social harm to actors more vulnerable to economic inequalities (Lunstrum et al. 2023) in the songbird trade system.

Songbird trade is useful case study for a more-than-human political ecology as it is embedded in complex and overlapping cultural systems (Javanese, footballing and more generic consumer cultures) and involves hundreds of species (Fiennes et al. 2024). But at the same time, the lessons we present here can be applied to other wildlife trades, including socially acceptable trades and those involving many species like invertebrates and plants. Ultimately, we hope this approach can be used to understand other illegal wildlife economies in terms of the social and cultural ideas that shape them, the material properties of traded entities, and how trade disrupts wild lives.

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Getting to know bird marketplaces

Walking into a bird market for the first time in Indonesia was an assault on the senses — the smell of ammonia from bird droppings, the heat from the dense rows of shops, the raucous noise of the birds, their singing, and the sounds of commerce, of human chatter and laughter. The cages holding the birds often jostled for space and it was difficult to distinguish the many different species on sale. The sensory overload was obscene, I got harassed in one marketplace where a trader grabbed me by the waist and tried to bring me over to his 'friend from the UK'.

I was seen as a foreigner, a white Westerner (a bule in Indonesian), a woman (though I am non-binary), a tourist – but it's safe to say my ability to blend in wasn't great. Sometimes people asked me if I was filming a documentary or working for an NGO. Sometimes they asked if I was working for a government ministry and seemed relaxed or non-plussed when I said no.

Covert marketplace surveys are questionable practice to me, though I'm also a terrible liar. I sent the marketplace authorities a letter explaining my research, then they gave me a tanda terima, a sort of receipt and then we showed that to people in the marketplace, and then said I am a student, doing my PhD (S3 in Bahasa gaul, or Indonesian slang) and working with Universitas Indonesia. I'd ask vendors, can I take some pictures, and that I am making an application to help people identify birds better.

You do get desensitized over time though, visiting wildlife marketplaces, which Smith and Heys[6] *argues that 'is then suppressed or avoided as it is "just part of the job". Over time, I grew to appreciate the fascination with seeing birds up close. Some of the birds are truly quite beautiful, particularly the brightly coloured and jewel-like birds were really eye catching. And then I felt sad that I'd never see birds this close in the wild and also I would be hard-pressed to go birding in Indonesia now unless, in a really remote place, I would never see that many species altogether in the wild. I went to Bali Barat National Park and genuinely struggled to see anything, we heard a few, but I realized the folly of my visions of national parks teeming with wildlife, most likely the result of Eurocentric wilderness notions that inevitably get fed to you during a conservation degree. I was so delighted seeing a sunbird or spiderhunter flit past me (I'm not sure which), on the back of a motorbike in Nusa Lembongan, that I nearly fell off. I realized it was because I had never seen one in the wild!*

[6] Smith and Heys, 'Ethical and Mental Health Considerations for Research into Trade and Trafficking of Natural Resources'.

Chapter 7. Discussion

Conservation challenges situate the management of natural resources within extraordinarily complex social, cultural, economic and political contexts. The resulting wicked problems are, by definition, immune to simple solutions. In this thesis, I explore one such conservation wicked problem - the Asian songbird trade - using a hierarchical approach that begins with a kernel of a solution and expands out to explore how the wider problem is structured. By beginning to unravel the wider complexity of the knot, it is possible to see why pulling on a single thread (e.g. a conservation technology) may loosen parts of the problem (e.g. potentially enhance species identification) whilst tightening others (e.g. undoing progress in social enforcement).

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is often quoted as aiming to make wildlife trade legal, sustainable, and traceable (CITES Secretariat 2022). I consider these aims through the case of the songbird trade. In this discussion, I argue for wildlife trade that is first safe (for humans and wildlife), sustainable, traceable and then legal.

This final discussion chapter brings together ideas from the thesis to synthesise novel insights. First, I review the results of the technology assessment process for the central intervention this thesis considers, an AI- enhanced taxonomic aid aimed at conservation law enforcement tasked with regulating legal bird trade in the global hotspot, Indonesia. I consider more just ways to use conservation technology, for instance to improve the traceability of trade, which may be more likely to trace if songbird trade is decriminalised or legalised, to avoid harm to human trade actors. Next is a more synthetic section that cuts across all chapters and discusses general themes around enforcement-based conservation approaches to IWT, particularly in the case of socially acceptable and speciose IWTs like the Indonesian songbird trade. I consider alternatives to enforcement that focuses on sustainable and safe trade for both people and birds. I expand upon critiques of how conservation currently addresses wildlife trade and racializes consumers, at odds with the cultural resurgence in birdkeeping in Indonesia and the counter-intuitive recent legal changes that further criminalise IWT in Indonesia, increasing the fines and maximum prison sentences.

Toward the end, I explore future directions for the field of wildlife trade research if it were to embrace some of the more-than-human and critical environmental justice-style approaches I consider. I argue for a more holistic form of conservation that considers the ‘double deaths’ that occur when species decline, resulting in the loss of individuals and endangering the status of the whole species (Rose et al. 2017). I first draw from the conclusions of **Chapter 5,** expanding upon my suggestion of a counter-narrative to the Asian Songbird Crisis, the Asian Songbird Challenge, and explore how this narrative can be used to explore interventions that focus on reducing the species diversity in trade. Lastly, to improve individual safety, in **Chapter 6** I explore a more-than-human approach that draws from understandings of the individual harm's birds experience, to suggest a series of socioecological harm reduction interventions. Beyond discussions of trade, I consider the feasibility of alternative livelihoods, and conservation basic income. Finally, I articulate my position of abolitionist approaches to conservation challenges like songbird trade and explore future directions for research.

7.1. Business as usual; where do technological interventions fit in the current Indonesian IWT enforcement system?

First, the thesis considers technology in the abstract, in terms of its development. **Chapter 2** showed that the development of AI-enhanced tools for identifying birds in occluded environments is possible, though the accuracy is not yet at an acceptable standard for use (the correct species was predicted 67% of the time). The model I built does not outperform other bird taxonomic aids like Merlin (an app specifically for birds) or Google Lens, both of which can provisionally identify birds in occluded images (i.e. behind bars). One limitation of **Chapter 2** is that it focuses strongly on the technology in itself, with less emphasis on how it is used. In **Chapter 4**, I build on this by exploring how the use of technology might fit into the roles and activities of potential end-users, and the implications of this

In terms of taxonomic aids, it is important that technologies are context-specific (i.e. trained on the specific data domain), and include other relevant knowledge for its use in practice; for instance, in **Chapter 4**, CLE voted for features like the Indonesian common name and the bird's national protection status to be included together with a correct identification. Still, these results showed that consensus is challenging to build on what features would be included in a taxonomic aid and different CLE agencies have conflicting requirements. For instance, BKSDA need to know the species identity (a conservation-oriented goal), whereas the police focus more on whether wildlife crime has occurred (legality), and the quarantine agency are primarily concerned with animal health and disease (presence of health certificates). These diverging demands and uses of a hypothetical taxonomic aid, in turn, reflect various components of the wickedness of songbird trade and challenge the applicability of technology to ameliorate unsustainable IWTs. In **Chapter 2**, I provide other tangible solutions to the problem of species identification, for instance, incorporating the skill of taxonomists, either in isolation or to validate machine learning results, as a 'human-in-the-loop' approach.

The overall ethical, social, and environmental implications of engaging in IWT underscore the intricate landscape of employing technology in the fight against illegal wildlife trade. In **Chapter 3**, I place the task of species identification in the context of CLE's broader work, understanding that inadequate species identification (a taxonomic barrier) is a facet of IWT as a wicked problem amongst other barriers they face like legal (problems with existing regulations), cultural (social acceptability of trade, corruption) and technical issues (staff shortages and lack of equipment).

Chapter 4 reveals that several barriers to conservation technology adoption did not appear to be present among our participants like the perception that conservation technology creates extra work or puts end-users under surveillance (as Kuiper et al. (2025) highlight amongst rangers in Zimbabwean protected areas using a technology known as SMART). On the contrary, participants embraced the concept of a taxonomic aid and were mostly optimistic about the integration of AI-enhanced taxonomic aids into their work.

The use of an AI-enhanced taxonomic aid would increase trade enforcement and compliance (Öckerman et al. 2024), through more surveillance of wildlife marketplaces and transit points, increasing seizures and potential confiscations, so in essence, detecting, stopping and deterring trade violations. Another part of tightening trade controls is the prosecution of trade violations (Öckerman et al. 2024). However, what **Chapter 4** shows is that a taxonomic aid is less useful in the prosecution of trade violations. Any trial, conviction or fine could not be based on the results of technology to prove the existence of IWT, i.e. through identifying a protected species. This is because trials rely on the verbal provision of evidence to confirm species' identity (**Chapter 3**).

7.1.1. Realities of conservation law enforcement practices in Indonesia

While any results from tools like these cannot be used without legal amendments to the current system, Steinke et al. (2022) suggest that failure should be part of any iterative design process and can generate new perspectives and that not all parts of solutions that emerge during digital design processes have to be linked to the product itself. One new perspective that emerged from this work is anti-IWT strategies and interventions rooted in discussions on sustainable trade rather than focusing on the conservation risk and relying on punitive enforcement to manage that.

The insights from **Chapter 3** show that CLE places less emphasis on the detection of IWT and more on its prevention through indirect means. They preferentially take a highly social, informal approach to songbird IWT, collaborating with vendors rather than adopting the heavy-handed method demanded by formal regulations (e.g. fines and arrests). This approach forms part of community engagement, a core tenet in traditional policing to enact ‘collaborative policing’ (Barnes and Eagle 2007).

This ‘socialisasi’ approach may be favoured because CLEOs exhibited a moral primacy towards trade actors’ livelihoods. In **Chapter 5**, a participant noted that local police in rural areas, like West Sumatra, often do not enforce laws against bird trade, viewing it as a way for people to sustain their livelihoods and feed their families. This result is consistent with the sympathies of authorities in Laos who were reticent to penalize wildlife sellers in marketplaces, favouring verbal warnings instead (Singh 2008), or Harrison et al.'s (2016) suggestion that authorities were reluctant to use heavy-handed approaches against hunters (across a range of countries in Southeast Asia) as they were often from ethnic minorities or economically marginalized communities. More loosely, it may be as simple as the fact that Indonesia has been described as a collectivist culture, where individuals share a sense of collective unity (Priwati and Sanitioso 2024), and CLE do not feel comfortable enforcing upon their compatriots.

Part of these community-based policing efforts are also concerned with the role of knowledge and intent. For instance, people may not be aware they are committing wildlife crimes (Cardoso et al. 2023). Thus, this is where socialization is a useful technique as it is less about assuming criminality and more about education. Maulany et al. (2021) did not find proof that data was collected to charge wildlife vendors during the inspections in Sulawesi bird markets. Arroyave et al. (2023) importantly highlights that top-down governance as an IWT approach often does not distinguish communities who opportunistically engage in IWT from the proactive components of such networks, in a study on IWT in Columbia. Other case studies (Gutierrez and Duffy 2024) have highlighted the sporadic and sometimes unintentional engagement of fishers with illegal European eel trade (*Anguilla anguilla*). Thus, these are complexities that CLE must consider in their decision-making on songbird IWT.

7.1.2. Why are bird consumers not the target?

In **Chapter 3**, I note that there is an absence of confiscations of protected birds from consumers, and this stage of the supply chain does not appear to be a major target for songbird enforcement. However, there are three factors that can explain this absence. One factor may be that the sheer volume of birds in ownership (in the order of tens of millions (Marshall et al. 2019) to hundreds of millions (Nuruliawati et al. 2023)) renders it physically infeasible to identify every instance of songbird IWT, complicated by difficulties in releasing confiscated individuals, which I will address later.

Another factor is that conservation law enforcement are consumers themselves. I discovered little about the prevalence of corruption amongst conservation law enforcement, though, in a focus group (that forms the basis for **Chapter 3**), one police officer mentioned he was bribed when attempting to purchase a Bali Myna (*Leucospar rothschildi*). Similarly, a bird harvester interviewed by Lucas (2011) reported seeing police officers and forestry officials buying birds in a shop he was delivering birds to. CLEOs also corroborated well-documented trends of members of the army and navy smuggling parrot from Papua to Java (Paddock 2002) and even from Australia (Australian Associated Press 2013).

The finding that CLE are also consumers suggests that they (understandably) do not want to incriminate themselves or the elites (Singh 2008), the affluent collectors I characterize in **Chapter 6.** CLE practice reflects the widespread nature of birdkeeping practices extending from the urban poor to the upper echelons of Indonesian society (Bubandt 2024). Lappe-Osthege and Duffy (2024) suggest there is a continuity between traditional practices, like hunting, with illicit business interests and political agendas, in their case for songbird meat hunting across Europe. Bubandt (2024) notes the use of songbird competitions in Java for political gain; political candidates may sponsor competitions, and this endears their electorate to them.

7.1.3. Where could technology improve the management of unsustainable bird trade?

From my results, it is not the case that AI cannot improve species identification, or that co-design with end-users is not possible or well received. It is more the case that other underexplored obstacles to the implementation of IWT technologies, like risks of corruption and co-option of technology by vendors, and fears of CLE around disrupting the livelihoods of trade actors (**Chapter 3**), combined with the eventuality that the results could not be used in prosecutions that are the issues.

The target of enforcement-based IWT prevention is to reduce trade-driven over-exploitation of protected or rare species. Yet, during this research, I started to question: what if my research and the results from technological interventions are used to incriminate people or perpetrate injustice to vulnerable people? Even if violent tough-on-crime policies are avoided (fines, arrests or imprisonment), certain trade actors would still be placed under surveillance if technology was used. The use of technology, even to ensure sustainable and traceable trade, is still a threat of violence.

Iordăchescu and Vasile (2023) outline four types of violence that have emerged in Romanian forests from the criminalization of timber logging, several of which are relevant in the case of the songbird trade, namely systemic and psychological violence. The fear of and threat of prosecution or a loss of livelihood is a form of psychological violence, which the use of an AI-enhanced taxonomic aid may only seek to enhance. Violence from criminalisation (i.e. raids from forestry departments) can threaten cooperation with conservation projects for targeted species (i.e. waterbirds) and make offenders fearful (McCarthy and Noor 1996). People may go to desperate lengths to escape prosecution. In Romania, small-scale timber entrepreneurs set themselves on fire (Iordăchescu and Vasile 2023). Couriers drowned 300 songbirds en-route to Indonesia to evade detection by authorities (Ramani and Clark-Shen 2019).

Results derived from taxonomic aids under the current laws could be used to take away people's livelihood and discriminate against trade actors, a systemic and slow form of violence (Iordăchescu and Vasile 2023). Given conservation law enforcement's concerns around affecting the livelihood of vendors, if all bird trade was legalized (or at least decriminalized), it would be possible to use the results of an AI tool to shift towards a sustainable and traceable monitoring system, as is currently being integrated into complex supply chains for several food products, like rice or beef (Astill et al. 2019). Astill et al. (2019) argue that the whole 'farm to fork' process should be transparent. Similarly, the process of 'forest to living room' (Collard and Dempsey 2013), could be made visible and ethical outside the parameters of punitive law enforcement.

If vendors are required to submit their trade records or use technology to prove they are not selling protected species, there may be literacy barriers. Low levels of literacy may complicate compliance and be beyond the systems vendors are comfortable with (e.g. pen and paper). If technology use is to be democratic and ethical, in theory, any person or subject vulnerable to the implications of its use should understand that a tool of this nature is in use.

Given what I discovered about conservation law enforcement practice, particularly towards songbird IWT, there are thus ways that emerge for how taxonomic aids could be used in a legalized and traceable system; 1. As an educational tool, 2. To inform the release of seized birds, with an overall focus on the transparency of the whole supply chain.

7.1.3.1. Technology for end markets: an educational tool

During focus groups in **Chapters 3** and **4**, CLEOs also suggested consumers (which could include themselves) as potential end-users of technology so they could be aware of whether they were purchasing protected species. Similarly, harvesters could use a taxonomic aid to check if they are trapping a protected species, or one known to be sensitive and therefore not worth trapping since mortality rates are high. This would save harvesters time, resources and money. What this shows, though, is that the most effective audience for IWT technology is unclear. Conversely, the different knowledge that actors involved in the songbird trade space possess could be of use to create a shared knowledge pool, which may contribute to sustainable trade solutions. Such an exercise may reveal there is not as much conflict between actors as imagined, even if they have different goals like preventing IWT (enforcement), demand reduction and boosting wild populations (conservation) and maintaining livelihoods or bird consumption habits (trade actors).

7.1.3.2. Using technology to inform the release of species

Exact species identification is sometimes a prerequisite for action (prosecuting under the conservation law but not for the quarantine law). At present, there seems to be a reliance on the quarantine law pathway rather than the conservation law for songbird trade enforcement, one reason for which is a lack of adequate species identification, which is required to charge someone under the remit of the conservation law (**Chapter 3**).

The quarantine law is largely invoked to conduct seizures, which appears to form the primary aim of direct law enforcement action (Guciano et al. 2024). Seizures prevent wild-songbirds from entering the market (Nuruliawati et al. 2023), though this action does not necessarily reduce harm to individual songbirds or benefit wild populations. Taxonomic aids could still have a role in identifying species, not to charge people under the conservation law, but to ensure faster release of seized birds at appropriate sites (**Chapter 3** revealed species identification can take up to three days).

Seizures and confiscations are a core part of the criminal justice response to wildlife crime (Saito 2025), though some criticise the utility of seizures, suggesting that they may stimulate greater killing of animals to supply demand (Felbab-Brown 2017, p.112). Collard (2014) argues that wildlife is made into a commodity upon capture but can be unmade through release and reintroduction. However, following seizures, given welfare conditions along the trade chain, and unsuitable accommodation during confiscations, many birds are often too sick or stressed to survive and be released (Wyatt et al. 2022; Saito 2025). During fieldwork, I was unable to gain access to government rescue centres, though one interviewee commented that birds are sometimes incinerated as seizure centres are overloaded. Similar actions were also reported for animal health reasons for non-native parrots in Norway (Sollund 2022).

If birds are suitable to be released, they are often not released in the correct part of their range (Nijman et al. 2018), for instance, an interviewee suggested that local forests may be more convenient than repatriating to remote islands in the bird's native range. Following the logic of conservation, it may be preferable to incinerate birds rather than risk damaging impacts from invasion in terms of releasing species in the wrong place and disrupting the gene pool of local populations.

There are also unknowns with releases, for instance relating to survival rates. If high-altitude species are released at lower elevations, it is unknown if they can adapt to new environments. Thus birds might never be able to be 'unmade' (Collard 2014), due to injury or struggling to acclimatise to new surroundings. The post-seizure process has been argued to thus extend commodification (Saito 2025) as animals may still face a life in captivity (Wyatt et al. 2022) and are seen as unfortunate collateral in enforcing IWT (Saito 2025). Still, my insights from **Chapter 6** using the Five Domains model could be used to at least improve the bird's experience in rescue centres, like focussing on the wellbeing of the bird, ensuring adequate cage size, nutrition, and providing covered areas for birds to retreat to.

7.1.4. Appropriate and just use of conservation technologies

Further, much of the conservation-related literature warns of the social contexts of conservation technology, though this is usually about concerns of technology being co-opted by the 'wrong people' and having unintended consequences for the wildlife it is seeking to protect. Still, AI itself has already fuelled wildlife trade, for instance, Facebook's recommendation algorithms show consumers new groups to join to buy wildlife or connect with vendors (Feddema et al. 2021), so co-option of new technologies should not be the primary concern.

What is potentially more concerning is the severe and unintended consequences of technology use that can result in communities being placed under surveillance. Simlai and Sandbrook (2024) found that drones for wildlife monitoring were used to enhance caste and gender inequalities in forest spaces of the Corbett Tiger Reserve in India, being used in a variety of disturbing ways by male forest guards, such as voyeuristically, to watch local women relieve themselves in the forest.

In a sector like conservation that, like many, is struggling to decolonize, the integration of AI may be misinformed in some case. By introducing AI to conservation situations, this may be reinscribing colonial notions and contributing to a new colonial world order (Hao and Freischlad 2022) that paves the way to expand the technological elite (Haklay 2013).

Iordăchescu et al. (2023) argue that current debates on IWT tend to target the wrong actors and generate misplaced solutions, and the dominance of existing narratives on the risks of using AI in conservation reflects these debates (i.e. focusing on the wrong social context). I cannot help but concur that technology would be a misplaced solution in the existing legal context of the songbird trade, and IWT technologies inevitably promote violent carceral strategies or the threat of violence to deter IWT.

Inspired by recent work considering the role of conservation technology as a distraction (Kuiper et al. 2025) or hype (Sandbrook 2025), I distil some of my insights on IWT technologies, particularly ones that use AI here, in a first attempt at a decision support tool for the equitable design of conservation AI technologies.

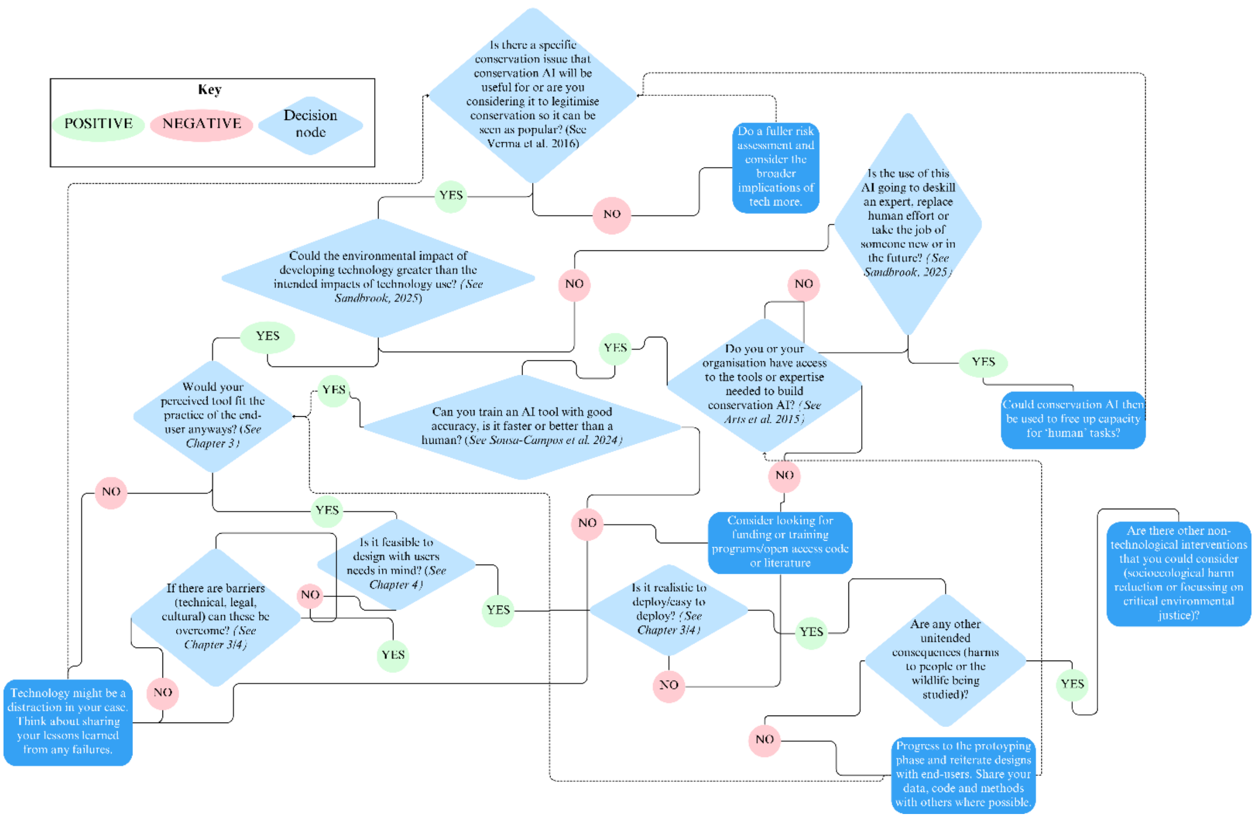

***Figure 7.1**: A flowchart that functions as a provocation for any conservation technology that uses artificial intelligence, though here I add specific data from the present studies assessment of AI enhanced species identification to improve detection of illegal songbird trade in Indonesia by conservation law enforcement end-users. Dotted lines indicate where outcomes feed back into decision nodes in an iterative process.*

7.2. Paradoxes

7.2.1. Increasing criminalization of IWT in Indonesia

It is not certain that punitive methods such as fines or prison are effective deterrents to committing IWT (Wilson and Boratto 2020). Elsewhere in Indonesia, fishers perceived fines for hunting threatened manta rays as unfair (Booth et al. 2023). In protected areas in Sumatra, local people broke rules due to the ambiguity of protected area boundaries when hunting or participating in logging (Ibbett et al. 2024). This suggests that local people critique and do not adhere to carceral policies attempting to manage IWT.

After I finished my fieldwork, paradoxically, the Indonesian government reinstated enforcement powers to the Balai Konservasi Sumber Daya Alam (BKSDA) in response to high rates of illegal wildlife trade (IWT) (Yulisman 2024). These changes reflect another trade control intervention, refining laws and regulations (Öckerman et al. 2024). The enactment of Law No. 32/2024 ensures a minimum sentence of three years with a maximum of 15 years (previously five) (Yulisman 2024). The new maximum fine has increased nearly 20-fold from approximately IDR 100,000,000 (GBP 4,926) to approximately IDR 2,000,717,620 (GBP 98,500) (Yulisman 2024). However, it is unlikely conservation law enforcement will use the maximum sentence for bird-related offences. The Indonesian government has a priority list of 25 species for conservation action, and the only songbird of six bird species on there is the Bali Starling (Kosasih 2016). Given that conservation law enforcement agencies are already underfunded (**Chapter 2**), they may lack the means to conduct more arrests, especially for low priority species.

There are also changes that may be met with more pushbacks from the birdkeeping community. For instance, protected wildlife outside Indonesia now has the same status upon entry. The Straw-headed Bulbul (*Pycnonotus zeylanicus*) remains unprotected in Indonesia as it is a highly coveted species in the trade. Given that Indonesian subpopulations have crashed (Chiok et al. 2020), most individuals are now sourced from Indonesian and Malaysian Borneo. If the individual comes from a Malaysian subpopulation, it is now protected, whereas if it is sourced in Indonesia, it is not. Though the provenance of seized individuals is often difficult to determine (Saito 2025), this adds further complexity to an already challenging system for conservation law enforcement to navigate (**Chapter 2**) and adds more (sub)species to identify and detect from the protected species list itself.

Whilst CLE may support further criminalization of wildlife trade for other species, the trends I found in research (**Chapter 2**) suggest that this is against the grain of their daily practice with songbird trade actors (i.e. tending more to socialization with vendors). Our results do not suggest that heavier fines and stricter penalties would be used to address songbird IWT, rather if CLE had a choice, they would expand upon existing indirect methods like the 'socialisasi' approach and scale them up or synergize local versus central regulations. Thus, I am skeptical that the further criminalization of IWT in Indonesia will filter through to songbird trade enforcement.

Though bird trade is not enforced in a militarised manner, introducing technology contributes to securitised modes of enforcement, as we have outlined. In turn, this could feed the perception of songbird IWT as a crisis. Wilson-Holt and Roe (2021) suggest that the perception of IWT as a crisis explains the prominence of law enforcement in strategies to reduce it

7.2.2. Socio-cultural factors of increasing bird trade

Relying on enforcement-based conservation measures suggests that, as a moral imperative, IWT is wrong and, therefore, should be punished. However, contemporary trends across various countries in Asia for re-engaging with cultural uses of wildlife suggest that a post-colonial reckoning is urgently needed in conservation regarding wildlife use. As explored in **Chapter 5**, conservation treats birds as a resource to be controlled, controlling people's behaviour in the meantime.

The social interest in the Golden Age of Indonesia (Planet Indonesia 2022) and the maintenance of birdkeeping practices as a source of national pride (Thomsen et al. 2024) is reminiscent of the resurgence of hongmu (tropical hardwood furniture, usually made from rosewood (Zhu and Zhu 2020)) and wenwan (toys of culture or sophistication (Lam 2018)) subcultures amongst Chinese consumers as people reclaim their cultural heritage following the massive geopolitical shifts of the late 90s and early 2000s.

As I explore in **Chapter 6**, songbird trade is now more socially acceptable than other cultural practices that entangle birds, like cockfights. Bubandt (2024) suggests that singing competitions increased because the police were cracking down on cockfights. Thus, increased law enforcement might have led to the establishment of singing competitions as *the* bird practice to engage with. Singing competitions are also endorsed by the elite elites (Singh 2008), like the president of Indonesia. The former president's (Joko Widodo) favourite species, the White-rumped Shama, has evaded uplisting on the protected list, and there are national singing competitions held at his residence in Bogor.

7.2.3. The failures of (enforcement-based) conservation

As I have outlined in **Chapter 6**, there are important class, gender and cultural dimensions in the songbird trade. One issue that our data does not represent well but has a key role in the trade is race and the politics of broader colonial power in Indonesia. Conservation has been described as a 'centralised machine' (Kashwan et al. 2021) and a 'colonial project' (Green 2023), where animals are rated more highly than people (Meijaard and Sheil 2008). As the alarm bells were being sounded for the Asian Songbird Crisis, depictions of Indonesian birdkeepers were problematic at best and racialized at worst. van Balen et al. (2000) characterised birdkeepers who desired rare birds, like birds of prey, as 'malevolent or ignorant.' Later, some conservationists, exemplified by Sykes (2017), advocate for demand reduction and changing the 'hearts and minds' of those engaged in birdkeeping traditions. These sentiments lead to the othering of birdkeepers, making them a 'conservation enemy' (Green 2025), and like other depictions of Asian wildlife consumers, are grounded in ideas such as orientalism and narratives of the subaltern (Margulies et al. 2019). These harmful imaginaries maintain human-nature dualisms and racialised justification for either a conservation that is exclusionary or cares more about the animal's life than the humans.

This 'us versus them' mentality (in the case of the Asian Songbird Crisis, the conservationists versus the birdkeepers) preserves the prioritization of Western voices in discussions on species conservation, placing less emphasis on the individual experiences of the same birds or that of human economic inequality and poverty. The ASC cannot rely on an implicit bias towards Western voices, a choice that is rooted in conservation's proximity to whiteness (Green 2023).

Beyond the concerns of racializing consumers, demand reduction efforts may also be challenging since there is an overlap between actor roles and consumer profiles. For instance, vendors are birdkeepers and consumers themselves (**Chapter 6**), and sometimes I observed vendors showing off their personal birds that have won competitions, which also function as a marketing ploy to attract customers.

Thus, I do not advocate for end-market interventions for the songbird trade. Marshall et al. (2020) found that hobbyists had the 'largest proportion of potentially wild-caught and threatened birds', though threatened expensive ornamental species are unaffordable for many consumers. As I outline in **Chapter 6**, there are also affluent collectors who have been an underappreciated and powerful actor in driving demands for a diverse range of species to enter the market and populate their menageries. However, not all wild-caught and threatened birds are protected, so this complicates consumer demand efforts if purchasing the bird is not actually illegal.

Reducing consumer demand for birds is problematic when it may constitute the main form of socialization for men of lower classes (**Chapter 6),** as well as enabling the elites (Singh 2008). The use of carceral (enforcement-heavy, punitive) agendas impacts marketplaces because the social space is now policed, inhibiting freedoms. One interesting point to highlight is that of the ancient Javanese conditions for a man to be a 'good man' (e.g. having a bird, a wife, a house, a horse and a dagger), there are at least two aspects that are interpreted differently in the modern age. For instance, *turangga*, in its pure form relates to a horse, whereas nowadays the most prized means of transport is a car; the *keris*, a ceremonial dagger is now interpreted as prestigious furniture or electrical appliances (Yulindrasari 2017). The fact songbirds have stayed so popular is telling, particularly important for men of lower classes to socialize around and with, as I discuss in **Chapter 6**, though other forms of socialising also exist that are not exclusively related to bird trade.

Foreign interference in Indonesia's natural resource management, motivated by conservation concerns, has not been well received. As one interviewee mentioned during data collection, Harrison Ford was accused of state harassment and threatened with deportation for questioning the environment minister on illegal logging (Hodal 2013). Dispute over the population status of recovering rhino and orangutan populations led to foreign scientists being banned or deported from Indonesia (Pearce 2023).

Another institution synonymous with foreign interference in Indonesia is the IUCN. Time lags in protection may be too slow for the pace of trade, and in any case, if the species is locally valuable, then the IUCN categories have little relevance, and the species may remain unprotected (**Chapter 5**). Take, for instance, the Straw-headed Bulbul (*Pycnonotus zeylanicus*), which is critically endangered yet found in every marketplace. Or the unprotected White-rumped Shama (*Copsychus malabaricus*) and the Oriental-magpie Robin (*Copsychus saularis*) that are locally extinct in Java and increasingly reliant on international trade in other subpopulations.

7.3. Species decline in the songbird trade: the Asian Songbird Challenge

In doing our focus group discussions, I found that the end-users of the proposed technology intervention had not heard of the ASC which is part of the everyday language of conservation organisations. This inspired **Chapter 5** on crisis narratives and led me to ponder how conservation thinks about species. Bubandt (2024) says, 'environmental concern for songbirds speaks from a position of care for species, natural habitats, and avian biodiversity'; however, the species-level rather than individual concern and the advocacy of ineffective measures like enforcement-based conservation says otherwise. How can conservation care for species and not individuals? How can conservation care for animals and not people? A totoaba hunter was quoted in a recent article (Shailer 2024) as saying: "This is my big question all the time: how can you prefer for an animal [the vaquita] to live while the people of the town die?"

The immediacy of crisis narratives is incompatible with 'daily wildlife trades' (Duffy 2022, p.35), like the Indonesian songbird trade, thus in **Chapter 5** I recommended using the 'Asian Songbird Challenge' for a nuanced perspective on the local contexts of bird trade, and drawing inspiration from overfishing narratives to inspire shifts to sustainable trade considerations away from legal-illegal binaries that are counterproductive to both humans and songbirds as I have outlined. Fishing and our description of the Asian Songbird Challenge can constitute a plausible counter-narrative to that of the Asian Songbird Crisis (Campbell 2000). Further, most songbirds have reproductive rates more like fish or plants than other high-value wildlife trades like rhinos or elephants.

In **Chapter 6**, more findings verify the suitability of the analogy to the fishing industry. Conversations with key informants provides evidence of fishing methods used to inspire bird harvests, such as the use of fishing nets and hooks. Thus, it is the materiality, the fleshy properties and the behaviour of birds that make them akin to fish. Commenting on migratory bird hunting in Egypt, Naguib (2021) reveals that 'many bird trappers are also fishermen'. To them, a school of fish is the same as a flock of birds.' Similarly, non-punitive models have been advanced for fisheries in Indonesia, like conditional payment schemes for fishers releasing rare sharks (Booth et al. 2023), and these models may apply to hunting birds.

This thesis suggests that shifting away from an enforcement-first approach for socially acceptable IWTs or contested illegalities is warranted. The bird trade enforcement system is too complex, and technological intervention for species identification in the form of a taxonomic aid is not feasible for several reasons. **Chapters 2, 3 and 4** highlight how even indirect approaches to enforcement, like those currently used, or legalising trade and focussing on less punitive measures and traceable trade, do not reduce harm to individual birds or lead to better conservation outcomes.

As I alluded to in **Chapter 5**, though it is sobering to think that species could go extinct from the Asian bird trade, there are not that many species that have been lost yet and there is potential for recovery. A deeper understanding is needed of the ecological impacts of wild bird harvest; though I have outlined some of the ecological dimensions in **Chapter 5**, speculating that it is possible the loss of abundant generalist species through wild harvest is of greater importance than losing rare species that may have little functional roles. However, geographically restricted but locally abundant rare species can still provide valuable services (Fiennes et al. 2024). Some participants noted local extirpations in **Chapter 5**, for instance of common species in their childhood, which represents both cultural and biological loss.

Research is scarce about welfare conditions in personal ownership of birds, though Collard and Dempsey (2013) note that when animals are rehomed with humans, the animals' lives are a shadow of their previous existence in the wild. This can indicate extinction of behaviours, as I alluded to in **Chapter 6**, but the loss of social groups, territories and other aspects of birdness. Sometimes, customers see themselves as liberators of caged animals from markets (like the people who buy pets in pet stores because they feel sorry for them), for instance I note similarities of saviourism mentalities amongst birdkeepers, as (potentially maligned) agents of conservation, with 'guerilla gardening' or 'citizen greening' enacted in response to government failings on environmental protection. Margulies (2023) calls these actors in the succulent trade 'Robin Hood conservationists', an archetypal character that risks stealing endangered plants as an act of species care.

The effects of the ASC in terms of rolling local extinctions (where species decline locally (extirpation) and thus harvesting 'rolls' onto other congeneric species or those with similar traits that function as near-substitutes for once favoured species) on community ecology and function are still poorly understood, and it is the taking of many species not the loss of one or two that is the wider problem. Thus, if it is about species care, reducing the overall diversity of trade is more important than individual acts in the name of protection like by Robin Hood conservationists (Margulies 2023).

7.3.1. Improving sustainability; reducing the species diversity of the bird market

Songbird trade is at the detriment of wild populations across the Indonesian archipelago (Nuruliawati et al. 2023). Though in **Chapter 5** I point out that this is not an extinction crisis, the ecological effects of rolling local extinctions are still unknown. It is also important to point out that the umbrella term of songbird trade omits other bird taxa that are implicated in the demand for songbirds. Approximately 90.3% of the birds owned by an estimated 91.9 million people were songbirds (Nuruliawati et al. 2023), though the remaining 9% of wild non-songbird species (i.e. parrots) likely include expensive ornamental species from other bird taxa.

The wider literature advocates for supply-side interventions; stopping the 'supply at the source' (Felbab-Brown 2017; Duffy 2022). Though I criticize the racialised connotations of demand reduction for IWT, it is evident that changes are warranted in terms of demand. Shifts towards the more sustainable use of birds would mean at a rate that does not lead to long-term decline (Hughes et al. 2023)). One way to ensure this shift could be to encourage people to purchase fewer birds.

7.3.2. No take zones or bans on sensitive or rare species

Engaging with a more pluralistic legal system (two or more forms of law (Trialfhianty et al. 2023)) could be used to enforce no-take zones, by integrating conservation with local customs (indigenous laws or customary laws). Further, in the spirit of this thesis' critiques of binaries in narratives on IWT, these measures should not just be fixed rules, but seasonal and shifting local no-takes that minimise impacts on both humans and birds.

Planet Indonesia, an NGO in West Kalimantan, Indonesian Borneo reported that in response to the decline of the White-rumped Shama (*Copsychus malabaricus*) due to its popularity in the songbird trade and the removal of its legal protection in Indonesia in 2018, customary indigenous leaders took proactive measures and successfully implemented and enforced a ban on capturing or killing this bird, helping to protect the species locally (Thung 2024).

Trialfhianty et al. (2023) found that more diverse community-level punishment approaches for those who broke the rules of marine protected areas were well received and perceived as based on local values. Customary management or adat law, unwritten and uncodified laws, are derived from social custom. This includes punishments like not being able to enter your village, fishing gear detention for a week or a fine of Rp3,500,000 (approximately GBP 70). Regarding support for pangolin conservation efforts in rural west Kalimantan, Borneo, villagers are more supportive of conservation when it aligns with their customs (Syafitri et al. 2024).

In theory, no-take zones should function as wildlife refuges and sustain populations in adjacent hunting areas (Cain et al. 2025). However, Cain et al. (2025) found that species richness was similar in areas with minimal hunting (e.g. no-take zones that function as wildlife refuges) and those heavily hunted by the Baka Pygmies in southeastern Cameroon; though there were notable differences in species occupancy and abundance and pronounced changes in wildlife assemblages at all trophic levels in the Baka hunting areas.

7.3.3. Captive breeding

For several IWTs, it has been suggested that consumers shift to farmed sources (Meeks et al. 2024). With other contributors, I reflect on the role of captive breeding in **Chapter 5**. However, several interviewees suggested that captive breeding is not a viable solution to meet either trade volume or species-specific demand; for instance, some species are impossible to encourage to breed. Captive breeding could form part of the solution, and I suspect that there are more species that can be captive bred than is currently known. However, it is important to note that captive bred birds will still spend a life in captivity, so adhering to the Five Domains model still needs to be stressed (**Chapter 6**). Expanding efforts for captive breeding should indirectly reduce the harvesting for their wild counterparts, reducing the diversity of species sold in marketplaces.

As I conclude in **Chapter 5**, there needs to be more dialogue between conservation breeding centres and captive breeding among birdkeepers. Further, the role of captive breeding for conservation needs to be strengthened; 10% of captive-bred stock is supposed to be returned to the wild (Nijman et al. 2018), though there is no administrative system to track these releases. Still the success of the Bali Myna could be built upon, where non-commercial breeding programs boosted populations combined with a nestbox program (Squires et al. 2024).

There are uncomfortable truths that conservation must accept to access or consider these partial solutions. Primarily, this revolves around the fact that the songbird trade is not culturally feasible to eradicate or even shift fully to solutions like captive breeding, which is only available for a limited number of species. As Lowen (2016) rightly suggests an 'outright ban on keeping birds would be an affront to Javanese identity… it would be as outrageous as the UK banning dog ownership'.

7.4. Individual level (harm reduction)

Termeer et al. (2019) warns that only partial solutions or small wins are possible for wicked problems. Conservation must account for the lives of Indigenous and local people if it is truly to be *for life* (Green 2023). If animals' lives are valued, then a focus on individual harm is necessary. Some of the following interventions may seem radical or controversial for a conservation audience, but as Margulies (2023) says in his book, *The Cactus Hunters*, conservation needs to make room for desire (for wildlife products).

Primarily, conservation and other disciplines should focus on reducing the need for IWT but accepting that songbird trade is not culturally feasible to eradicate nor that quick fixes like captive-breeding and demand reduction are possible. There needs to be a way to enhance the possibilities of sustainable trade, whilst minimizing the impacts on trade actors' livelihoods.

If up to a million birds are harvested every year in Indonesia (People Not Poaching 2018), and only a small fraction are surviving at the point of sale, then actions to minimize individual harms (improve welfare and reduce mortality) across all the stages of the supply chain could have an impact on wild populations, boosting conservation outcomes.

As Duffy and Brockington (2022) suggest, the benefits and harms of wildlife trade are unevenly distributed in the human and non-human worlds. Given that human-bird relations are based on non-consensual power dynamics in captivity, I do not consider the bird as consenting, however considerations of bird's experiences in ownerships are beyond the scope of this study.

Given that the songbird trade experiences high social acceptability (Marshall et al. 2020; Fiennes et al. 2024), I tend towards interventions that do not aim to eradicate the songbird trade. In the spirit of this, the end of **Chapter 6** considers a series of interventions that arise from my findings that are more just at social, ecological and individual levels to humans and birds and may encourage more of a shift to sustainable use of birds, following the proposition of Hübschle and Margulies (2024) to adopt a socioecological harm reduction approach to IWT. To me, safe trade is that which goes to lengths to acknowledge and reduce the individual harms birds face, i.e. using less destructive harvesting and transport methods.

These interventions reflect the four-stage supply chain I mapped in **Chapter 6**; harvesters, intermediaries (transit), vendors and consumers. These interventions include identifying sensitive species, implementing payment schemes in situ, and phasing out harmful practices like the use of birdlime. Improving transport conditions, enhancing marketplace environments, and promoting welfare models among birdkeepers are also recommended. I advocate for phasing out of birdlime, which damages flight feathers (Platt et al. 2012) and lowers the value of the bird (**Chapter 5**) whilst promoting peer-to-peer training from expert mist-net trappers to less experienced harvesters and funding mist-nets for harvesters without the means to purchase them.

Some conservationists have started to advocate for 'harm reduction policing approaches' for other more lucrative IWTs, such as the totoaba trade, which is heavily entwined with driving the severe decline of the vaquita in the Gulf of Mexico. Eliminating the most harmful practices to vaquitas, like gillnetting, while promoting less harmful methods like using hooked lines would allow local hunters to maintain their income and avoid conflict with drug cartels (Shailer 2024).

7.5. Interventions outside the supply chain for birds: addressing human inequalities

Though the specific harm committed to birds is deeply important to highlight, the more-than-human approach outlined in **Chapter 6** helps build an understanding of the wildlife trade in general. My results suggest that gender, class and economic inequality dimensions dictate social relations between actors and influence the larger economic context driving bird trade and how harms are intensified towards low value species.

Interventions that address sustainability at the species level and safety, at the individual level do not necessarily reduce social harm to actors more vulnerable to economic inequalities (Lunstrum et al. 2023) in the songbird trade system, such as those who rely on external investment or are tied to the patronage of more powerful actors.

As Harrison et al. (2016) notes, there does not appear to have been any research on the potential viability of different permitted hunting systems in Southeast Asia. Through shifting away from enforcement-first approaches, the suggestions I have provided here to reduce the supply of wild songbirds by focussing on reducing harmful practices, local management of no-take zones and captive breeding are ripe areas for future research.

There are also ways that wild harvesting could be disincentivized such as through the provision of alternative livelihoods. Usually, discussions of this kind tend towards promoting environmentally sustainable livelihoods, like eco-tourism for instance. However, some of these forms of work are still precarious (i.e. seasonal, visitor-depending, poor returns) and are not always feasible as the area must also be somewhere people want to visit. Duck farming and mushroom cultivation had been previously suggested for bird hunters in Krangkeng Central Java, bearing in mind the above mentioned issues (McCarthy and Noor 1996). Other alternatives could be encouraging people towards industries that are not necessarily environmentally focused, like working in local factories or manufacturing. Others have reported interest from bird trade actors in transitioning into coffee farming and opening convenience stores (Freischlad 2018), though candidates lacked capital and know-how.

If alternative livelihoods to songbird harvesting are to be suggested, they must ideally improve upon existing labour conditions. In **Chapter 6**, I outline the role of investors, for harvesters, bird shop owners and door-to-door sellers, highlighting the instability and precarity that some actors experience in their livelihoods. Some vendors rely on bird trade for their primary income (Miller et al. 2019) and some harvesters may not be able to feed their families without catching birds (Lucas

2011). Naguib (2021) points out that bird harvesters in Egypt are also fishers. Similarly, an informal conversation with field collaborators suggested that some farmers had turned to bird hunting during the COVID-19 pandemic. However, the extent to which full-time alternative livelihoods are needed is unclear and may only be partial roles for some actors, which could be viewed as a more achievable goal than replacing someone's full income.

7.5.1. Conservation basic income

Beyond the (pedantic) conditionality of conservation payment schemes or the sometimes-forced nature of alternative livelihood shifts, conservation basic income may offer a radical redressing of the economic inequalities in IWT. Conservation basic income (CBI) is a proposal for an unconditional cash transfer to individuals residing in conservation areas (de Lange et al. 2023). This idea takes inspiration from the concept of universal basic income, a strategy designed to address wealth distribution.

There are already well-established social forestry programs, across Indonesia, where unconditional payments are made to poor families living in tropical forests and this program has contributed to reduced deforestation (de Lange et al. 2023). However, there are some issues with this scheme in terms of gender equity (Yuliati et al. 2024), with women struggling to access management opportunities and participate more democratically in decision-making. Though the funding mechanisms are undecided for schemes like this, de Lange et al. 2023) suggest a system of public financing, where government subsidies for energy and agricultural production could be redirected to CBI schemes amid broader consideration of tax reforms and debt justice. Further, CBI does not explicitly apply to residents in areas that are not considered important for conservation.

Marsden et al. (2023), on noting severe declines in mountainous bird species in West Java, suggest 'working with local communities at individual sites either to protect remaining populations or to create socio-ecological conditions suitable for re-introductions'. Unless conservation projects are prepared to hire members of local communities en-masse, conservation basic income, though it is a front-end loaded investment, seems like the only viable solution in addressing underlying drivers of IWT like broader poverty and economic inequality.

7.6. Next steps

7.6.1. Feasible recommendations for CLE

In **Chapter 1,** I alluded to plans to feed research back to local communities. Given CBI and abolitionist approaches to conservation will need extensive and evidenced research, and legal reforms can take several years (for instance it was nearly 20 years between updates for Indonesia's conservation law), I bring together constructive evidence to strengthen existing CLE relating to songbirds, in non-punitive and sustainable ways. I set out a series of ways my results will be conveyed back to conservation law enforcement in the form of a written report in Indonesian and a seminar to our participants (depending on interest)., with the support of field partners.

1. Results from **Chapters 3 and 4** suggest a need to formalise existing communications over species identifications; for instance, the use of WhatsApp to crowdsource species identification amongst colleagues could be replaced with an iNaturalist project for bird marketplaces that taxonomists and birders could join to help with the process of species identification and improve the monitoring of diversity across Indonesia's many marketplaces. This approach is low cost and makes use of existing tools. Similarly, results from **Chapter 2** suggest that Merlin and GoogleLens (also free and available on Android phones) are capable of identifying birds in complex environments like behind cage bars.
2. Given the main interaction of CLE with trade actors appears to be through socialisation, I suggest also using this as an opportunity not just for educating vendors on the protected species list, but also to suggest tangible ways they can minimise harm to birds (as outlined in **Chapter 6)**, for instance putting in barriers between humans visiting stalls and birds in cages as well as avoiding stacking. Insights from vignettes with veterinarians could be used to generate guidelines on proper nutrition and other husbandry aspects
3. The results of **Chapter 6** suggest a precarious workplace for vendors, CLE would be best placed to build on the 'socialisasi' approach to incorporate discussions on poverty alleviation and development, and they are primed to investigate the motivations of vendors and understand their situation - do they need financial or technical support for instance? NGOs are already doing similar consultations on alternative livelihoods with bird vendors (Freischlad 2018) and this could be an excellent route to share expertise and funding.
4. Lastly, given their concern for the livelihoods of trade actors, future research and interactions with CLE could consider ways that decriminalisation or legalisation of bird trade could work in practice, along with local market management authorities.

7.6.2. Understanding motivations for engaging in songbird IWT

Green's (2025) critical environmental justice framework for the study of IWT can be used to consider the motivations for why people engage with IWT. For instance, there is no indication that conservation basic income would stop the harvesting of birds, but it may ensure better financial security for poorer harvesters or less powerful trade actors experiencing economic inequalities.

Further, as it stands, the motivations for harvesters supplying birds are under-explored. Some people harvest recreationally in urban (Jepson et al. 2011) and rural areas (Marshall et al. 2020), which may be an opportunity to socialize with friends (Marshall et al. 2020) or reinforce masculinity (Maderspacher 2022).

The reality is many people commit crimes because their basic social needs are not met. Conservation is always very concerned with how poor rural communities spend their time and money and how they impact wildlife in their surrounding environment, rather than if they can make an adequate living (McCarthy and Noor 1996). To highlight some of the economic inequalities, as I alluded to in **Chapter 6**, harvesters and less powerful vendors are reliant on external financing. Naguib (2021) suggest that most hunters are willing to cooperate with conservation efforts if their basic needs are met.

7.6.3. Instigating a critical environmental justice approach: queer ecologies?

By considering elements of race, class and gender this is a step towards more race-aware approaches to IWT (Green 2025). For instance, studies on the role of gender within wildlife trade often treat or assume gender as binary, though I do not take this position as a non-binary person, and I see gender as a spectrum and a social construct. A queer ecology perspective could be used to investigate the intricacies around the gendered consumption of birds. Queer or trans ecology frameworks reject binaries, dualisms and dichotomies and highlight the perils of relying on cisnormative perspectives, thus queer(er) ideas of nature involve pluralising human-nature relationships, which may be of use to explore in efforts to examine more-than-human experiences in political ecology praxis (Vakoch 2021, p.66).

Little is known about how and if women and gender-non-conforming people consume birds in Indonesia. There may be different solutions or insights that we may miss by assuming consumers are only cisgender men. In Pontianak, Kalimantan, 17% of bird shop owners are women (presumably *cisgender* women) (Miller et al. 2019). There were women selling birds or feed in Java, but they were often accompanied by men I perceived were their husbands.

Indonesia also has a rich history of trans identities. For instance *waria*, individuals who are assigned male at birth who embody feminine self-presentation or claim to have a female soul (Fadhlina 2024). We know little about whether trans men consume birds and if they are also pressured to own birds as a means of performing their masculinity in Javan culture.

7.6.4. Exploring abolitionist approaches to illegal, unsustainable, undetectable and unsafe trade

Treating IWT seriously does not mean it has to be seen as a serious crime through securitizing and militarizing IWT enforcement, and this approach has done little to tangibly 'stem the flow' of IWT. The narrow lens of enforcement-first (or carceral approaches) that conservation has aligned itself to obscures other more holistic and potentially long-lasting and effective interventions that consider the safety of humans and wildlife.

Green (2025) notes that those most vulnerable to the social and ecological ramifications of IWT are those most likely to be prosecuted. Anecdotally, recidivism rates for songbird IWT are high, which is unsurprising when a review of "tough-on-crime" sentencing policies found that such policies are ineffective at reducing crime rates and recidivism (Wilson and Boratto 2020). If a trade actor is convicted of a songbird-related crime, they are either receiving a fine, a prison sentence, or both (**Chapter 3**). If they are sentenced, they will be sent to a local prison along with other offenders for violent crimes (towards people). Though the number of IWT prisoners in Indonesia is unknown, the occupancy rate of prisons is at 196% of their capacity (Hamja 2024).

To my knowledge, within prison, there are no attempts at IWT-specific reform, for instance, education or tangible provision of alternative livelihoods as a form of rehabilitation. Paudel et al. (2020) found some evidence of IWT prisoners in Nepal expressing an intention to return to IWT after their release. In other geographies, like the United Kingdom, there have been community service programs for those who were charged with illegal possession of bird eggs (Wellsmith 2011).

Abolition ecologies offer a way forward to imagine an enforcement-free world to manage IWT, dismantling oppressive systems and fostering equitable environmental practices. Abolition ecology presents an approach to exploring, unravelling, and resisting racial capitalism and environmental racism as interlocking and mutually generative systems (Heynen and Ybarra 2021), shifting away from the use of prisons.

Implicitly, an abolition perspective on conservation needs to be entwined with a critical environmental justice framework. I consider an abolition conservation perspective as one that moves away from any punitive enforcement measure to achieve conservation goals (de Jong et al. 2024). Still, exploring abolitionist approaches to wildlife trade is part of a wider conversation about decolonizing conservation, the academy and the abolition of prisons in broader society, beyond the scope of my modest discussion chapter. Importantly, further research is warranted on how to operationalise abolitionist approaches to conservation, given that abolition ecology could be perceived as an abstract concept, with many inter-related parts. However, I have taken steps to explore abolition ecologies of the songbird trade through a digital storytelling project, Uncaged Conservation. Others have been exploring the use of zines to navigate the contours of Venus flytrap (*Dionaea muscipula*) harvesting in North Carolina, USA, through the lens of socio-ecological and racial justice.

7.7. Concluding remarks

Here I outline a technology assessment methodology that explores how taxonomic aids could dissolve taxonomic barriers to addressing songbird IWT, but that could be counter-productive to conservation law enforcement's priorities of indirect socialisation with vendors. In considering technology in its broader social and political context I conclude that it is counter-productive for intervening in trade controls for widespread songbird IWT in Indonesia. That said, pulling at the thread of technology, hoping to use a co-productivist and participatory design approach with conservation law enforcement as end-users, I come to terms with the failings of criminal justice responses and crisis narratives in enforcement-based conservation.

As is the case with IWTs prone to complex patterns of substitutions and rolling local extinctions (Fiennes et al. 2024), there is always the next shiny thing, as we 'fish down the food web' or 'hunt across the forest' in the case of birds. In this discussion, I go some way to highlight how hunting across the forest could be limited whilst still contending with the need to preserve cultural practices, addressing some of the challenges to the governance of the songbird trade, like high species diversity and poor welfare conditions.

Towards the end of the thesis, I suggest future directions of research. Lahsen and Turnhout (2021), in the case of global change science, suggests that there is more focus on the ecological effects of climate change (the symptom) rather than addressing the socio-political challenges that drive it (the cause). Similarly, it is abundantly clear that in its current state Indonesian bird trade is not sustainable or well-regulated, though with plausible explanations. What is urgently needed is a clearer understanding of the social justice issues humans face from partaking in wildlife trade. The interventions I have briefly considered here need further research to locate them in the context of histories, communities and ecosystems (Green 2025), particularly around the social justice issues Indigenous and local communities face from carceral conservation strategies, as I have already highlighted the harms birds face along the supply chain. Green (2025) stresses that fundamentally, only Indigenous people and local communities can define the contours of just IWT interventions. The concept of seed sovereignty, where local people are entitled to commodify and sell resources (e.g. seeds) if they have historically lived on the land (Singh 2021), could have relevance to wildlife trade, i.e. wildlife sovereignty.

It is important to recognize the violence birds experience and make victims visible while respecting cultural traditions that involve diverse wildlife uses, especially in the Global South (Oommen et al. 2019). Conservation's reliance on the prison industrial complex for handling environmental crime offenders (de Jong et al. 2024) raises ethical concerns (e.g. Paudel et al.'s (2020) observation that poor and Indigenous community members form the majority of the IWT prison population in Nepal). We should critically engage with abolitionist approaches to conservation and consider reducing individual harm to animals as a means for broader species conservation. Additionally, we must question the ethics of imprisoning people for environmental crimes when caging protected bird species is deemed wrong by conservation, as is the broader concept of owning wild birds.

As I have shown here, though species identification is a key facet of diverse IWT markets, technological interventions to improve it have far-reaching implications and risk reinforcing the status quo of securitising IWTs by focusing on intelligence gathering and perpetuating conservation violence or the threats thereof. Critically, more interdisciplinary and radical approaches are needed to reduce and prevent IWT that are fundamentally rooted in questions of safety and sustainability for people and birds rather than enforcement-focused and punitive. Classical anti-IWT strategies are based on profoundly unequal power asymmetries between states, international conservation movements, people, and wildlife. By returning wildlife crime to a local and shared context, we can stop treating both people and animals as subjects to be controlled and, instead, help them to thrive.

7.8. References

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Appendices

Appendix A – Ethics Approval

Proportional ethics approval from the Faculty of Biological Sciences Research Ethics Committee

Dear Sicily

LTSBIO-039 - Contextualising perceptions and solutions to the Asian Songbird Extinction Crisis

NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic.

I am pleased to inform you that the above research ethics application has been reviewed by Faculty of Biological Sciences Research Ethics Committee (FBS FREC) and on behalf of the Chair, I can confirm a favourable ethical opinion based on the documentation received at date of this email.

Please retain this email as evidence of approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://ris.leeds.ac.uk/research-ethics-and-integrity/applying-for-an-amendment/ or contact the Research Ethics Administrator for further information (FBSResearchEthics@leeds.ac.uk) if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Best wishes
George
On behalf of Dr Dave Lewis, Acting Chair, FBS FREC

Ethical clearance from the Ethics Committee on Social Studies and Humanities National Research and Innovation Agency (NRIA) of Indonesia.

KOMISI ETIK BIDANG SOSIAL HUMANIORA
BADAN RISET DAN INOVASI NASIONAL

Gedung B.J. Habibie Lantai 8
Jalan M.H. Thamrin No. 8, Jakarta Pusat 10340
Laman: https://klirensetik.brin.go.id/, email: klirensetik@brin.go.id

ETHICAL CLEARANCE DECISION LETTER
Social Studies and Humanities Research
Ref No.: 534 /KE.01/SK/11/2022

Herewith The Ethics Committee on Social Studies and Humanities National Research and Innovation Agency (NRIA) informs that,

Research Title	:	Opportunities for Co-Design of Technology to Address The Southeast Asian Illegal Bird Trade
Application Number	:	05102022000027
Unit/Institution	:	School of Biology, Faculty of Biological Sciences, University of Leeds
Research Coordinator	:	Sicily Fiennes

Has been evaluated in the meeting on October 12th, 2022 .

Based on the results of the meeting, the Ethics Committee on Social Studies and Humanities NRIA has made the decision: **The research with the application number has met the ethical clearance requirements with a period of research from November 2022 to May 2023.**

Researchers remain obligated to:

a. Comply with health protocols related to Covid-19 Pandemic that apply at the research locations.
b. Submit a new application shall there be amendment to research design or research subject.
c. Submit a report when the field research has been completed.
d. Provide information if there is a change in location, research time and/or termination ahead of schedule.

The Ethical Committee on Social Studies and Humanities NRIA has the right to conduct monitoring during the research.

Jakarta, 4th of November 2022
Chief of Ethical Committee on Social Studies
and Humanities
National Research and Innovation Agency

TT ELEKTRONIK

Dr. Augustina Situmorang, M.A.

Dokumen ini ditandatangani secara elektronik menggunakan sertifikat dari BSrE, silahkan lakukan verifikasi pada dokumen elektronik yang dapat diunduh dengan melakukan scan QR Code

Ethics approval from the University of Leeds Business, Earth & Environment, Social Sciences (AREA FREC) Committee, 2023.

Dear Sicily Fiennes,

0419 - Resubmission of 'Opportunities for co-design of technology to address the Southeast Asian Songbird Crisis'

NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic.

I am pleased to inform you that the above research ethics application has been reviewed by the Business, Earth & Environment, Social Sciences (AREA FREC) Committee and on behalf of the Chair, I can confirm a favourable ethical opinion based on the documentation received at date of this email.

Please retain this email as evidence of approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see https://ris.leeds.ac.uk/research-ethics-and-integrity/applying-for-an-amendment/ or contact the Research Ethics Administrator for further information (EthicsEnquiries@leeds.ac.uk) if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Best wishes

Rachel De Souza, Lead Research Ethics & Governance Administrator, Secretariat

On behalf of Dr Judith Hanks, Chair, AREA FREC

Appendix B – Chapter 2

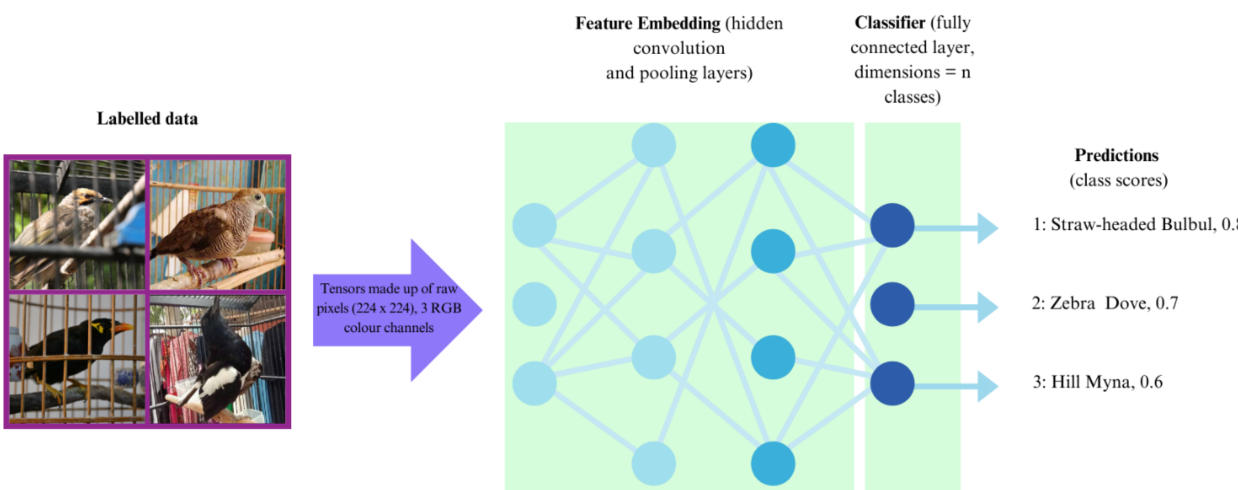


***Figure B1**: Visualisation of a convolutional neural network. Image credits all Google Searches with the exception of the top left image taken by Sicily Fiennes.*

Table B1: Definitions for common terms used in image-based machine learning that relate to training and evaluating models.

This paper is not intended as a thorough introduction to machine learning, though we attempt to provide a concise and comprehensive summary of image-based classification in this contribution. Some further context and definitions of key terms can be seen below.

Stage	Term	Definition
Building your model	Activation function	A tool in each layer of a neural network that decides how to turn inputs into outputs, passing them along to the next layer. We used the softmax function, which converts raw output scores (logits) of a model into probabilities for each class that sum to 1, where each value corresponds to the likelihood of the input belonging to a particular class. The top-1 accuracy is the highest and most probable class.
	Learning rate	Controls how fast the model learns. A high rate is quick, but risks missing the optimal solution; a low rate is slow and risks getting stuck in local minima.
	Loss function	Measures the "distance" between predictions and their corresponding ground truth labels. The model optimizes for a minimal loss; if predictions are wrong, the model is penalized; once the loss reaches a minimum, in theory likelihoods for the correct classes will be high.
	Epochs	The number of times the model looks at all the training data. Too few or too many can hurt performance, so it needs to be just right.
	Batch size	Splits the training data into smaller chunks for processing. Small chunks are fast but may make mistakes, while bigger chunks are slower but steadier.
	Number of layers	Simple problems need fewer layers; complex ones need more, though this is both a question of network breadth and depth.
Evaluation	Precision	Total true positives divided by the sum of the true positives and false positives.

	Recall	Total true positives divided by the sum of the true positives and the false negatives.
	Average Precision	Area under the precision-recall curve.
	mean Average Precision (mAP)	The average of the average precision (AP) over all classes, at a number of recall levels. AP is more accurate than the F1scores because it considers the PR relation globally - goal is 0.8 +.
	Accuracy	The accuracy is the percentage of the total images (in any dataset) that are correctly classified (Natesan et al. 2019). Sum of positives (whether true or false) over all data. An accuracy of one would mean that all the images are correctly classified.
	F1 score	The F1 score (also known as the harmonic mean) is a combined measure calculated from the precision and recall and is thought to be a more valid measure of model performance than the test accuracy, as it gives a better measure of the incorrectly classified cases because it weights precision and recalls equally.

The precision, recall and F1 score are defined using the following equations.

$$Precision = \frac{true\ positives}{true\ positives + false\ positives}$$

$$Recall = \frac{true\ positives}{true\ positives + false\ negatives}$$

$$F1 = 2 \cdot \frac{precision \cdot recall}{recision + recall}$$

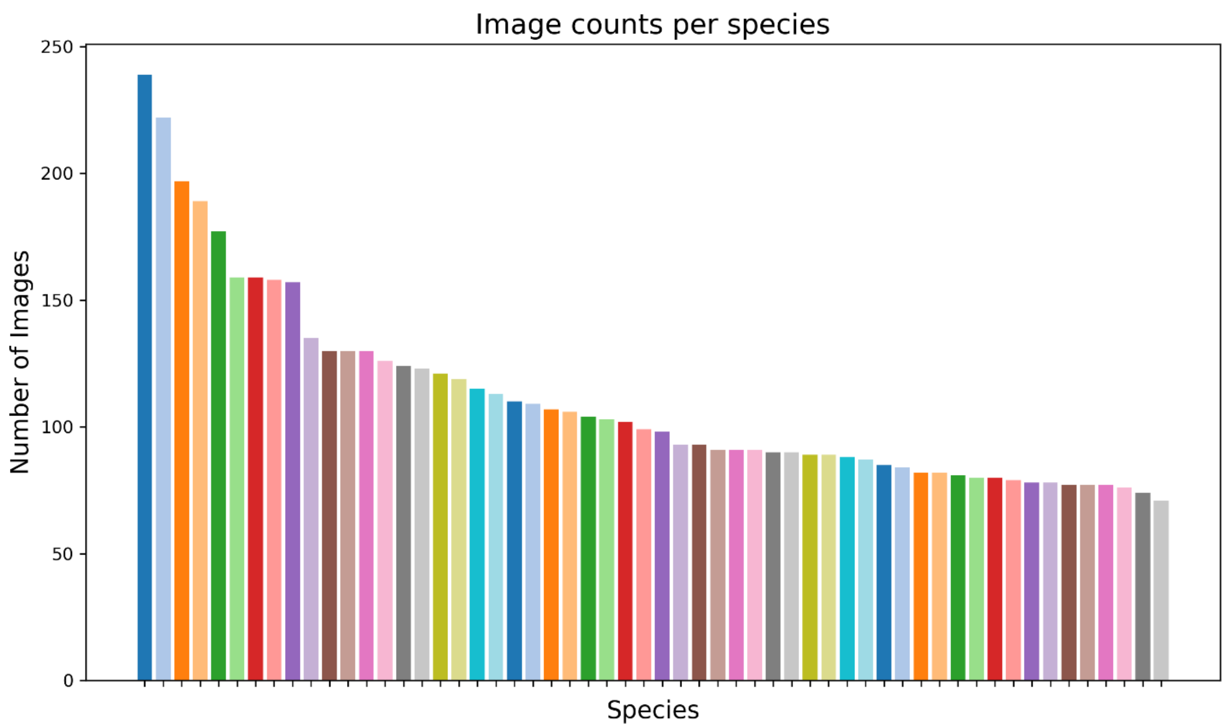


Figure B2: *Distribution of data across the 56 species in the dataset, data is imbalanced but not severely so. There is limited data (n = 100 or less) for most of the species included in the model.*

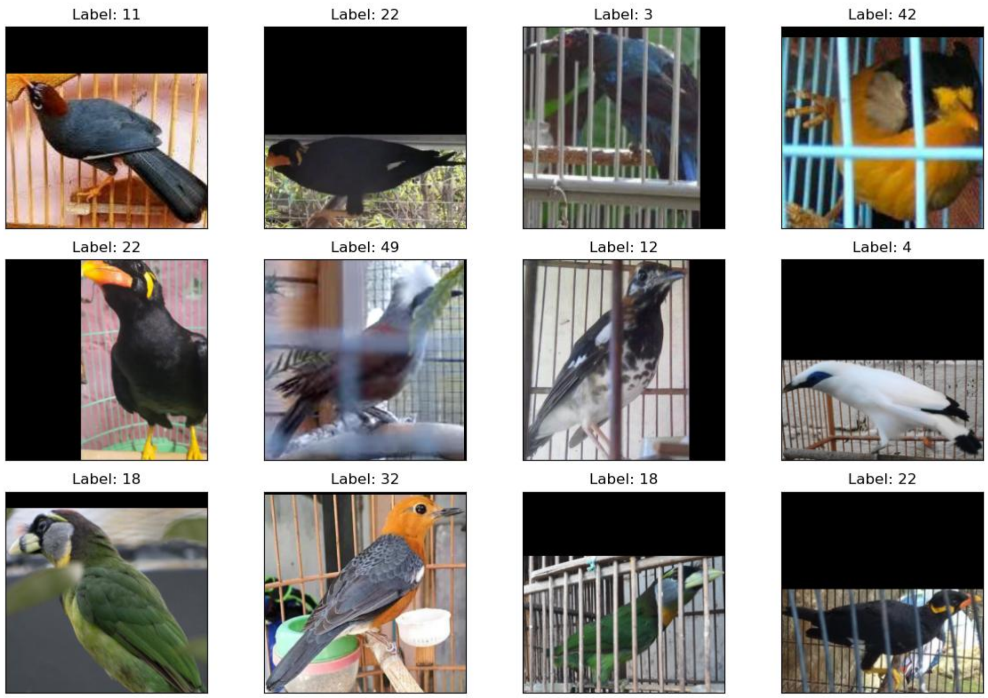


Figure B3: *Visualisation of the padding technique we used in the PyTorch dataloader to maintain the aspect ratio of images input to the model. Image credits from anonymous contributors.*

B.2. Extended Methods

B.2.1. Data Collection

1. **Phase One (2020-2021)**

The data contributed were images of birds in various trade-relevant environments, including urban marketplaces, during seizures and personal ownership. Data collection was carried out in two phases. Most data (70%) was contributed from bird markets across Southeast Asia (Indonesia, China, Singapore, Vietnam, Thailand, Malaysia), conservation breeding centres (Cikananga Conservation Breeding Centre and Prigen Conservation Breeding Ark), zoos (Chester Zoo and Singapore Zoo), museums (Leeds Discovery Centre, World Museum Liverpool, National History Museum London), and public forums on social media websites (Baidu, Facebook).

In terms of publicly available data on the surface web, we identified groups on social media using the Indonesian words '*burung*' and '*kicau mania*' (songbird craze), followed by consumer hotspots in Java, e.g. Jakarta, Bandung and Yogyakarta. Some images were also downloaded from Google when searching for the English name, plus keywords such as cage, caged, pet, and trade. Some Chinese species (Fiennes et al. 2021) are also sold in Indonesia, so we also searched two separate sites (Baidu Tupian, https://image.baidu.com/ and Baidu Tieba, https://tieba.baidu.com/) for relevant species.

The individual birds varied in terms of species, age, gender, and size, whereas images differed in sensor types, dimensions, resolution, angle, and pose. All photos mostly comprised single, alive, adult, or juvenile individuals. Individuals were sometimes photographed in cages with other birds, though every image concentrates on one individual.

In the winter of 2021, two authors visited the Leeds Discovery Centre and Liverpool Museums collections. In the summer of 2022, more data was collected at the Natural History Museum store in London. Similarly, Chester Zoo was visited in the winter of 2021 to take photos of live, captive individuals of species also sold in the illegal wildlife trade.

There are some similarities in the conditions of traded birds in marketplaces to mounted museum specimens. Many birds in marketplaces have lost feathers and, in general, are not in good health (Chng et al. 2015). The same is true of museum specimens. Another physical attribute that both live and dead birds have in these contexts is a loss of colour. Some traded species experience what is known as the blue-winged phenomenon. The blue phenomenon is where the bird becomes a dull blue colour kept in captivity (Nijman et al. 2017) due to a lack of lutein pigment typically found in their insectivorous diet. The colour of museum specimens can also fade over time due to light exposure. However, this fading is not usually considered significant enough to mispresent the colouration of wild birds. In a study on long-tailed manakins (*Chiroxiphia linearis*) Doucet and Hill (2009) found that reflectance spectra (e.g. colouration) from museum specimens were similar to wild birds.

Other work has also demonstrated the feasibility of training convolutional neural networks on image data taken of museum specimens. Schuettpelz et al. (2017) trained a model that could detect mercury-stained herbarium specimens from images with 90% accuracy. Other promising results have been found using digitised natural history collections to identify carabid beetles (Hansen et al. 2020).

Choosing to photograph museum specimens gives the great advantage of an immobile subject. This means that a single bird can be photographed from many different angles, with many different camera settings. A single cage wall was also used to provide occluded photos and, again, this can be highly manipulated.

The drawbacks of working with museum objects are the variety of mounts, or lack of mounts, the birds are held on. It is difficult to position a bird appropriately if it is not already attached to a floor-mounted stand. Problems may also occur with species accuracy of historic taxidermy. Some specimens do not have the correctly coloured glass eyes or beaks and feet have been painted with non-accurate colours.

2. Phase Two (2023)

Data providers generally contributed images with pre-existing labels. Several authors reviewed these classifications or suggested a manual classification for contributed images using the Birds of the Indonesian Archipelago Field Guide (Eaton et al. 2021). The classification was lengthy for cryptic or sympatric species as they can be similar in size, shape, and colouration (Gooliaff and Hodges 2018). Though the labelling error is unknown, we approximate that nearly all the annotations are correct.

B2.2. Data Preprocessing

1. Labeling and Cropping

Once data were gathered and labelled, we used the YOLOv5 model (Jocher 2020), without further training, to generate bounding boxes around birds where it could detect them. These boxes were reviewed in LabelMe, an open-source data labeling tool (https://github.com/wkentaro/labelme), and manually drawn where the model did not detect a bird. After editing the extent of the boxes, the images were cropped and then reorganized into species-specific folders. Each image depicts a single target (a bird), and the subsequent image classification model assigns one label (an abbreviated species name) per image.

2. Dataset Compilation

We collated 6,214 images of 56 bird species with various image sizes. The dataset totaled 0.795 GB including all training, validation, and test splits. Merlin, a vast bird identification application for wild species, uses a minimum of 50 images per species (Team Merlin 2024), whereas Adhikari et al. (2024) used at least 136 images per species. Since data availability for traded species is a bottleneck, we used 70 images per species as a requirement for inclusion into the model (the image count long-tailed distribution can be seen in Figure S2). The dataset was unbalanced, though this reflected the real-life data distribution in our domain (i.e. we have fewer images for rarer and less popular species).

3. Data Splitting

We used an 80/20 split to randomly allocate 80% of the data for training (4971 images) and 20% for validation (1243 images). The test set was independently constructed and contained 157 images, mostly taken on mobile phones, for a subset of 46 species and stored separately from the training data. These images were collected by the first author at Sukahaji Market in Bandung, West Java. Some images were from a public iNaturalist project where data was also sourced for training, though the test images were uploaded after training data was collected (Table S3). One exception was the Orange-headed Thrush (*Geokichla citrina*), which was common in our dataset. Still, there was no suitable new iNaturalist data or recent marketplace data, so for this species we searched online for Creative Commons photographs. Our test set can be seen as independent but within the data distribution of the rest of the training data.

4. Data Independence

We encountered significant challenges related to data independence, e.g. sequences of images captured of the same bird using the same camera simultaneously. For example, having 100 photos of the same bird taken in one day does not provide a representative sample for training our models.

We had to introduce variation into our dataset to ensure robust model training. Given that many birds do not remain still, we collected multiple images, but we recognised that having too many pictures of the same individual could limit the model's learning potential. To address this, we established a maximum of 20 images per individual, ensuring these were taken from different poses if taken on the same camera. Images of the same bird captured by other cameras were not counted towards this limit. If images are all of the same few birds, this can artificially increase the accuracy: for instance, the Merlin team noted this for some species (Team Merlin 2024).

B2.3. Model Building

1. Model Selection

We used a RestNet-18 model pre-trained on ImageNet, and we fine-tuned the final layer and retrained it to identify birds from traded images. ResNet-18 is lightweight (fast to download and load in with Pytorch for transfer learning, with only 18 layers)

2. Data Loading

A random seed was set before training to ensure reproducibility. Images were inputted in tensor format, as batches, and of dimensions 224 by 224 pixels into ResNet-18. The outputs from the model are softmax scores, which show a range of confidence scores from the model on what it thinks is the most likely label for a set of images (Figure S1). Softmax scores range between 0 and 1, with the label assigned to the image as the highest score.

Given that the contributed images were all various sizes, we employed padding to resize them (Figure S5). Padding ensures that each image fits the uniform 224 x 224 size for ResNet-18, by adding extra space around the image without warping the image (altering the aspect ratio). If an image is in portrait orientation (taller than wide), padding is added to the sides. If it is landscape (wider than it is tall), padding is added to the top and bottom. The padded images are then passed to the model to be read as tensors.

3. Hyperparameter Tuning

When training image recognition networks, models are trained for a number of epochs, where an epoch is a complete pass over all of the data. The number of epochs refers to the number of times a model has seen a full dataset. Hyperparameters control the number of images used in every batch (a smaller subset of the dataset that is processed iteratively over an epoch), minimize error (the optimizer) and determine how a network is trained (the learning rate) (Kandel and Castelli 2020). Different configurations of hyperparameters can be tested to see which results in the highest accuracy on the validation data (best possible outcome during training), a process also known as tuning (Zhang et al. 2022).

Given the reasonable computing resources at our disposal, we used a large batch size (n = 128) since large batches give the model a greater opportunity to learn as more data is processed at each epoch (Kandel and Castelli 2020). We used the RMSProp optimiser for model optimisation and set the batch size to 128. The learning rates were chosen from empirical trials starting with a standard rate of 0.001 and increasing and decreasing from this rate (Table S2).

These are hyperparameters that are either computationally expensive or result in small or incremental changes in model performance. We conducted experiments to fine-tune relevant hyperparameters to ascertain which configuration produced the best accuracy and mean average precision on our training and validation data. We conducted experiments in the following stages (increasing epochs, applying augmentations, learning rate variation and scheduling), to see which, if any, had the biggest effect on boosting model performance.

First, we assessed how performance varied when the epochs were increased (n = 25, 50, 75, 100). We adjusted one augmentation at a time (e.g., test each method at a likelihood of0.3, increase the probability of the best-performing ones, and then look at combinations of the top performing methods). We set the same probability for each augmentation to help maintain consistency and make it easier to understand the effects each augmentation might have. Then, combine these best-performing augmentations in a new experiment, as combining poorly performing ones is unlikely to improve results. The augmentations are described in more detail below.

Primary

Primary augmentations are geometric transformations that alter the spatial properties of images, in our case, to simulate different orientations of birds. Other augmentations, like horizontal or vertical flipping, keep the bird's appearance the same but introduce variation into a dataset that otherwise is not heterogeneous enough.

Intensity

Intensity-based augmentations are colour space transformations that modify the colour properties of images, such as lighting, colour saturation, and contrast. These augmentations help the model generalise across different lighting conditions without overemphasising one specific type. We used image sharpness as an intensity-based augmentation.

Occlusion

Occlusion augmentations inject noise into images and are considered heavy augmentations as they significantly alter images. For instance, using occlusion augmentations like blur reflects blur levels already present in the training set; for example, given that birds can be very active in cages, blur reflects this motion. Another occlusion augmentation is random erasing; these augmentations would randomly mask out rectangular sections of the image, simulating occlusion.We applied Gaussian Blur with a kernel size of 7. With a 7x7 kernel, the image will have a moderate blur. This will render details of the bird 'smoothed' out (i.e. the edges less distinct), but the species should still be identifiable.

After ascertaining which augmentation(s) performed best (i.e. had the best accuracy and mean average precision, mAP (mAP is the average of the precision across all classes, calculated at various recall levels) on the training data, we tested the effect of the learning rate and, later, a learning rate scheduler on these metrics.

4. **Training**

   We used CometML to log all experiments, and a full list of the experiments we ran can be seen in Table B2.

B2.4. Evaluation

1. **Accuracy and Precision**

As a benchmark to assess the performance of models with different hyperparameter configurations, we used the following metrics: accuracy, mean average precision (mAP), precision, recall and the F1 score (all defined in Table B1). The final iteration of these experiments is the best-performing and optimal model on the validation set. We used this model for inference with the test set.

2. Confusion Matrix

To further visualize the model performance, we plotted a confusion matrix on the validation data. In a confusion matrix, the x axis represents predicted labels, the y axis represents the true labels and the diagonal, i.e. where species 1 aligns with species 1, represents the true positives, any off diagonals, in either rows or columns represent misclassifications. The rows demonstrate false positives; for instance, the model predicts the label of species 1, but it is species 2 or 3 and so forth. The columns demonstrate the false negatives, so the true label is species 1 but the model has incorrectly predicted the label as species 2 or 3. The matrix reveals specifically what species the model confuses with others.

3. Phylogenetic Analysis

If classes of birds that are more ecologically distinct perform better, closely related species may be more likely to be confused with each other. However, this may also be related to image quality (which we calculate as the average pixels per image across a species) and sample size. Generally, models with more samples per class (Schneider et al. 2020), perform better. For other bird identification models, like Merlin, images are usually benchmarked at a high quality, so low quality images are not included.

We added a heatmap to the phylogeny that shows taxonomic relatedness, image quality and number of samples per class (species), and the F1 score from the best performing model on the validation data. The F1 score is already between 0 and 1, though the other variables were normalized, so an image quality of 1 represents the species with the highest average pixels across all the samples, and a sample size of 1 represents the species with the most image data. Given that it is an older phylogeny, some of the Latin names for species are not up to date, and notably, the Javan Pied Starling (*Gracupica jalla)* is not treated yet split from the nominate species in the genus, the Indian or Asian Pied Starling (*Sturnus contra*). The same goes for van Hasselt's Sunbird (*Leptocoma brasiliana*), which is not split from its nominate species the Purple-throated Sunbird, (*Nectarinia sperata*), and lastly, for Swinhoe's

White-eye (*Zosterops simplex*), is represented as the Mountain White-eye (*Zosterops japonicus*), despite now being acknowledged as a separate, congeneric species (Bruslund 2021).

4. Test set evaluation

For the test data set, we exported the true and predicted labels, the accuracy score per image, and added a human expert-verified identification. We also used the Top 2 accuracy, which measures the proportion of times the true label is among the top two predicted labels with the highest confidence scores.

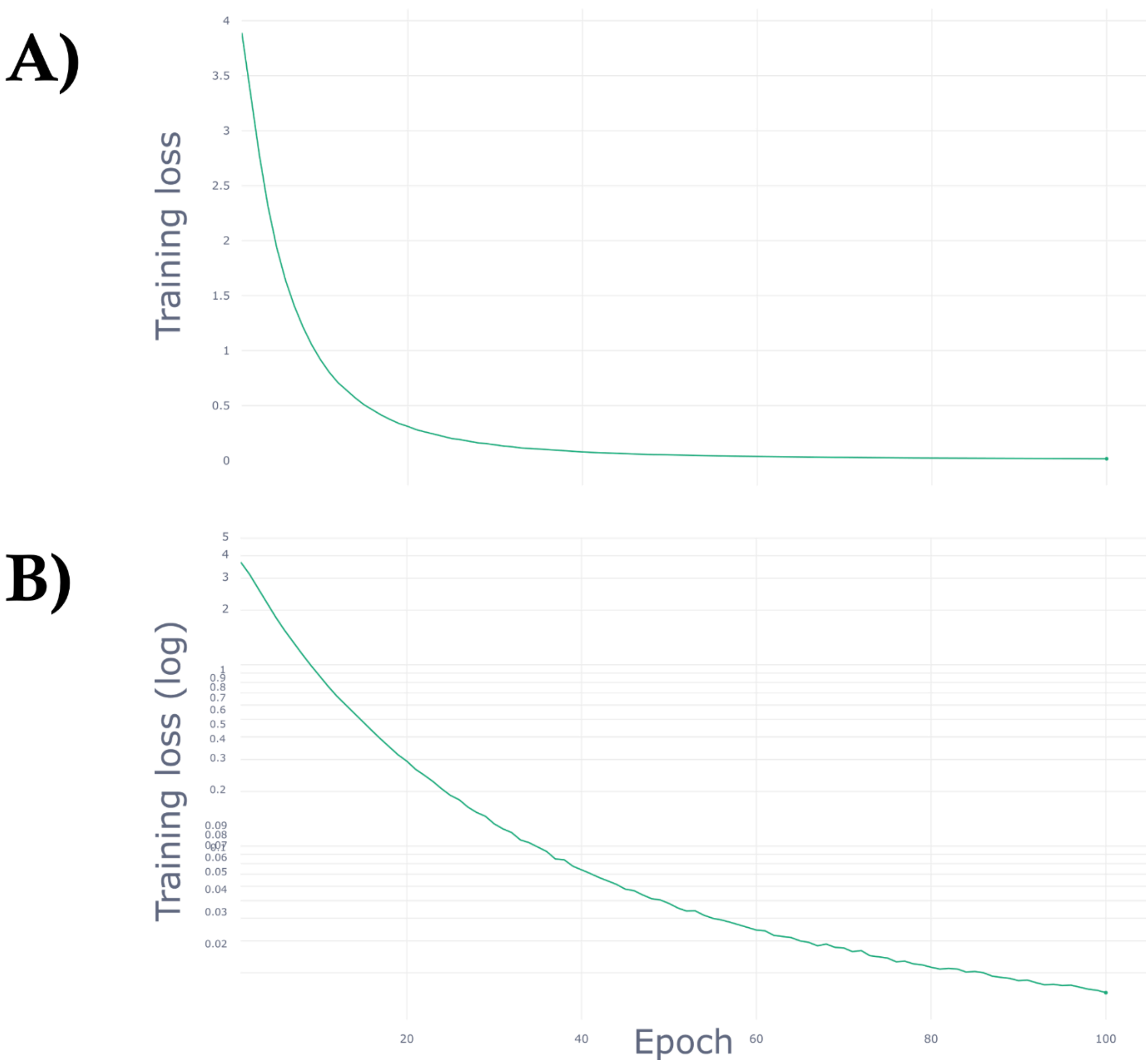


Figure B4*: The loss* ***A)*** *and* ***B)*** *the log loss of the training loss for the best performing image-classification model decreases and plateaus over epochs.*

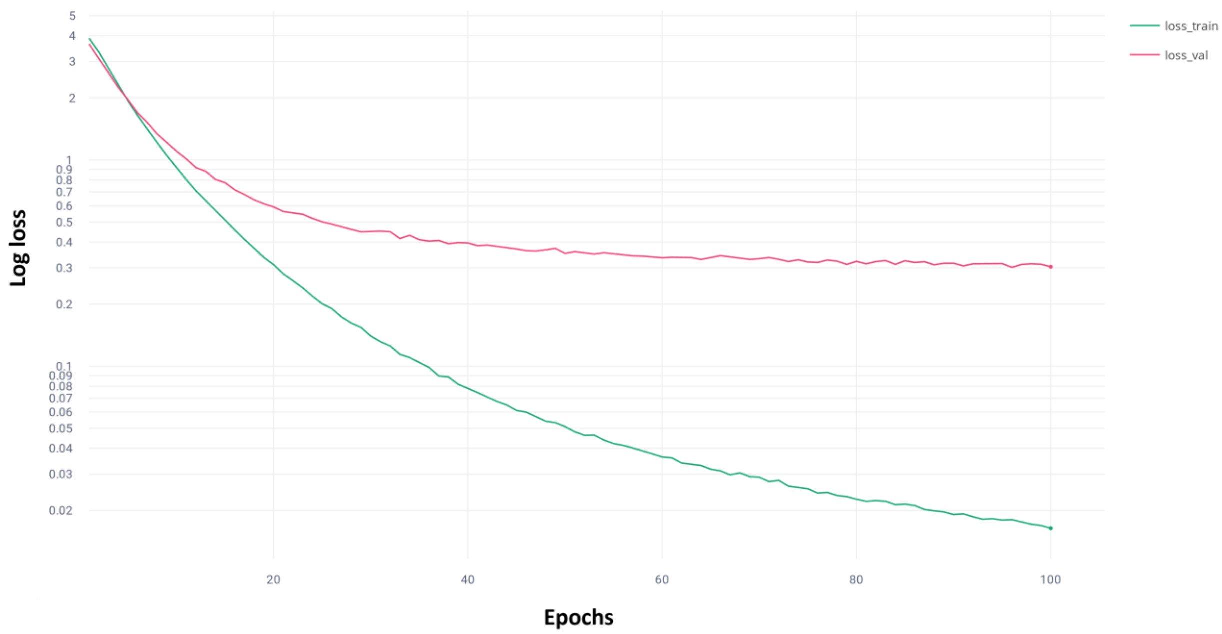


Figure B5: *The log loss of the training and validation loss for the best performing image-classification model decreases and plateaus over epochs.*

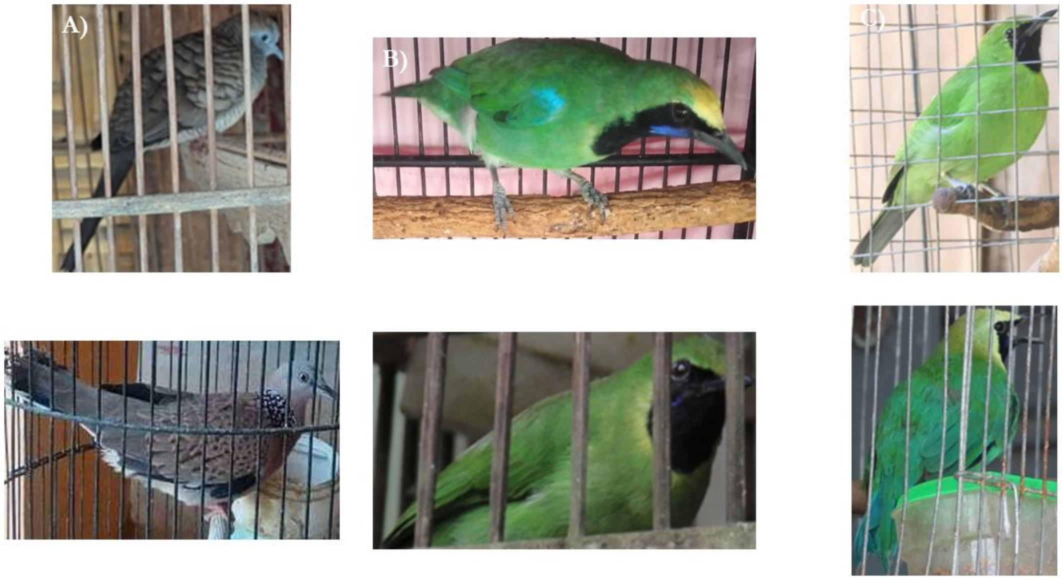


Figure B6*: Examples of closely related species that the model gets confused with each other, contributors following the Latin name, usernames are from iNaturalist users: A) Zebra Doves (Geopelia striata) (dearco) with Spotted Doves (Spilopelia chinensis) (cantikadara), B) Golden-fronted Leafbird (Chloropsis aurifrons) (Ganjar Cahyadi) with the Lesser Green Leafbird (Chloropsis cyanopogon) (Sicily Fiennes), and C) the Lesser Green Leafbird (Chloropsis cyanopogon) (biom) with the Blue-winged Leafbird (Chloropsis moluccensis) (biom).*

B2.5. Experiment data

All experiments can be viewed in CometML, with the training and validation accuracy, loss and mean average precision available: https://www.comet.com/sicily-f/cagedbird-classifier/view/new/panels.

Table B2: List of experiment names and hyperparameters varied over a hyperparameter tuning exercise.

Hyperameter varied	Experiment Name	Translation of name
Epochs	ep25_56sp_anone_lr1e-3_snone_orig	25 epochs, 56 species, no augmentation, learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep50_56sp_anone_lr1e-3_snone_orig	50 epochs, 56 species, no augmentation, learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep75_56sp_anone_lr1e-3_snone_orig	75 epochs, 56 species, no augmentation, learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_anone_lr1e-3_snone_orig	100 epochs, 56 species, no augmentation, learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep150_56sp_anone_lr1e-3_snone_orig	150 epochs, 56 species, no augmentation, learning rate of 0.001, no use of scheduler, original data, no upsampling
Augmentation	ep100_56sp_asharp_lr1e-3_snone_orig	100 epochs, 56 species, augmentation by varying sharpness (p=0.3), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_ablur_lr1e-3_snone_orig	100 epochs, 56 species, augmentation using Gaussian blur, learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_averflip_lr1e-3_snone_orig	100 epochs, 56 species, augmentation using vertical flipping (p=0.3), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_ahorflip_lr1e-3_snone_orig	100 epochs, 56 species, augmentation using horitzontal flipping (p=0.3), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_arota_lr1e-3_snone_orig	100 epochs, 56 species, augmentation by rotating (10 degrees), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_aerase_lr1e-3_snone_orig	100 epochs, 56 species, augmentation using random erasing (p=0.3), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_ahorflip0.5_lr1e-3_snone_orig	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_arota15_lr1e-3_snone_orig	100 epochs, 56 species, augmentation by rotating (15 degrees), learning rate of 0.001, no use of scheduler, original data, no upsampling
	ep100_56sp_aerase0.5_lr1e-3_snone_orig	100 epochs, 56 species, augmentation using random erasing (p=0.5), learning rate of 0.001, no use of scheduler, original data, no upsampling
Learning rate	ep100_56sp_ahorflip0.5_lr1e-2_snone_orig	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.01, no use of scheduler, original data, no upsampling
	ep100_56sp_ahorflip0.5_lr1e-4_snone_orig	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.0001, no use of scheduler, original data, no upsampling
	ep100_56sp_acombo_lr5e-5_snone_orig	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.0005, no use of scheduler, original data, no upsampling

Learning rate scheduling	ep100_56sp_ahorflip0.5_lr1e-2_s5	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.01, learning rate is reduced by 10% every 5 epochs, original data, no upsampling
	ep100_56sp_ahorflip0.5_lr1e-2_s10	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.01, learning rate is reduced by 10% every 10 epochs, original data, no upsampling
	ep100_56sp_ahorflip0.5_lr1e-2_scustom	100 epochs, 56 species, augmentation using horizontal flipping (p=0.5), learning rate of 0.01, learning rate is reduced by 10% after 50 epochs, then again at 75, original data, no upsampling

Table B3: *Species in the test data that were found on iNaturalist (post 2022). The data contributors for each species are attributed. Images were downloaded under a Creative Commons license from the public iNaturalist project, Wild Birds in Cages (https://www.inaturalist.org/projects/wild-birds-in-cages).*

Species	**Contributor**
Asian Fairy-bluebird, *Irena puella*	banditto, goodfy
Blue-crowned Hanging-parrot, *Loriculus galgulus*	invasiveplanet, titustay
Blue-masked Leafbird, *Chloropsis venusta*	neontetraploid
Black-throated Laughingthrush, *Ianthocincla chinensis*	liuguangyu, migonnav, mizudori
Blue-winged Leafbird, *Chloropsis moluccensis*	banyumili, biom
Chestnut-capped Thrush, *Geokichla interpres*	ryanmaulana
Chinese Hwamei, *Garrulax canorus*	gbno, wangwang2018
Common Hill Myna, *Gracula religiosa*	nereston, redpandacat, wangwang2018, yannbigant
Crested Lark, *Galerida cristata*	cypselurus
Crested Myna, *Acridotheres cristatellus*	ls0
Eurasian Hoopoe, *Upupa* epops	mario_x_garofano
Eurasian Jay, *Garrulus glandarius*	abyss
Eurasian Siskin, *Spinus spinus*	natasha_pan, rayee
Greater Green Leafbird, *Chloropsis sonnerati*	lakell
Japanese Grosbeak, *Eophona personata*	idiossimus, yohoyoho
Javan Pied Starling, *Gracupica jalla*	listiana, pathfinder
Lesser Green Leafbird, *Chloropsis cyanopogon*	biom
Orange-headed Thrush, *Geokichla citrina*	neontetraploid
Oriental Magpie-robin, *Copsychus saularis*	tnhan, yvetteamplified
Red-billed Leiothrix, *Leiothrix lutea*	allay, dolordebarriga
Red-whiskered Bulbul, *Pycnonotus jocosus*	vicait, yannbiggant, yylin
Scaly-breasted Munia, *Lonchura punctulata*	brindley, pierre_driessen
Scarlet Minivet, *Pericrocotus speciosus*	possumsend
Siberian Rubythroat, *Luscinia calliope*	redpandacat
Straw-headed Bulbul, *Pycnonotus zeylanicus*	scarlet
Spotted Dove, *Spilopelia chinensis*	cantikadara2, human_ecologist, ruthapp
Swinhoe's White-eye, *Zosterops simplex*	jianstargazer
White-crested Laughingthrush, *Garrulax leucolophus*	rubanhussain, wild_wanderers_ff
White-headed Munia, *Lonchura maja*	adeliawijiastuti08, ruliasalsabila
White-rumped Shama, *Copsychus malabaricus*	abenincegioda2023
Yellow-bellied Tit, *Pardaliparus venustulus*	redpandacat
Zebra Dove, *Geopelia striata*	dearco, kokom_komariyah

To briefly compare the results of our model with the Merlin bird identification application and Google Lens, we show the test image, and whether it is correctly identified (top-1 accuracy) (yes/no) by our model A), Merlin B) or Google Lens C). There are four examples we show; the Asian Fairy-bluebird (*Irena puella*) (Figure B6), the Bali Myna (*Leucospar rothschildi* (Figure B7), the White-rumped Shama (*Copsychus malabaricus*) (Figure B8) and the Common Green Magpie (*Cissa chinensis*) (Figure B9). We use Merlin without filtering by geographic location, to compare the results more accurately.

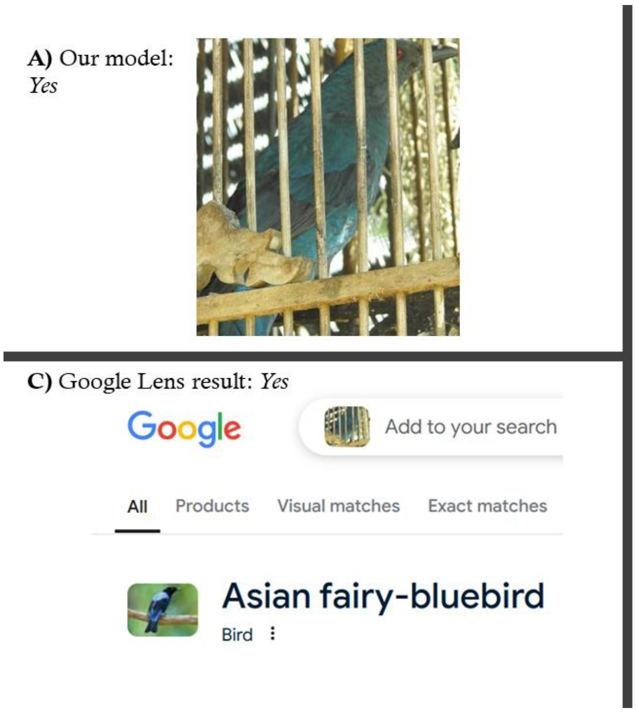


Figure B7*: The results of our model (****A),*** *Merlin* ***(B)*** *and Google Lens* ***(C)*** *for an image of an Asian Fairy-bluebird (Irena puella).*

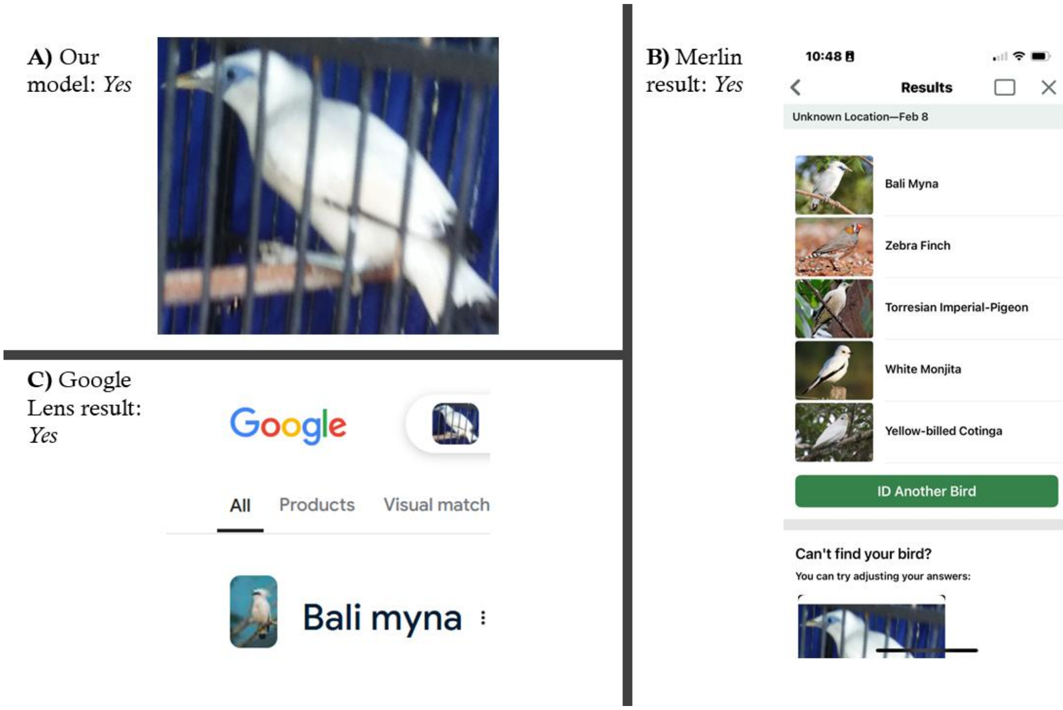
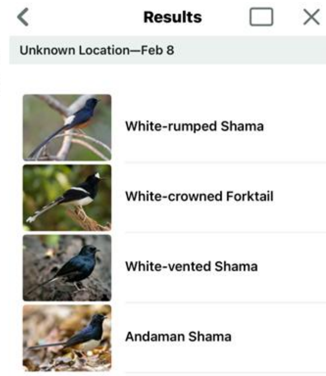


***Figure B8**: The results of our model **(A),** Merlin **(B)** and Google Lens (C) for an image of a Bali Myna (Leucospar rothschildi).*

A) Our model: *Yes*

B) Merlin result: *Yes*



C) Google Lens result: *Yes*

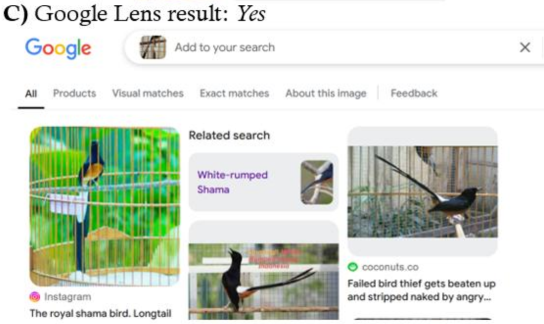


Figure B9*: The results of our model* ***(A),*** *Merlin* ***(B)*** *and Google Lens* ***(C)*** *for an image of a White-rumped Shama (Copsychus malabaricus).*

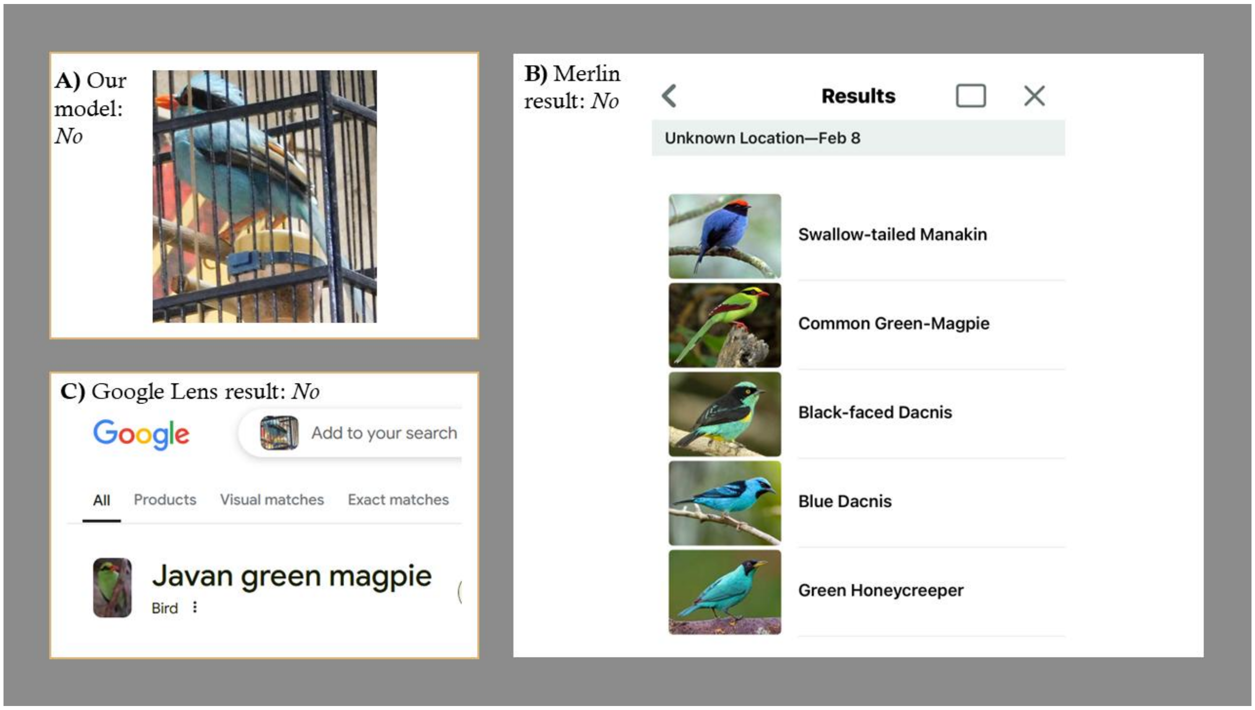


***Figure B10**: The results of our model **(A),** Merlin **(B)** and Google Lens **(C)** for an image of a Common Green Magpie (Cissa chinensis).*

B2.6. References

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Appendix C – Interview, focus group and user-centred design session guides used in Chapters 3-6

Guide 1: Focus group structure and script for workshops with Indonesian conservation law enforcement, in English and Indonesian.

The workshops were structured in five stages:

1. Short introduction and project presentation – *empathy and understanding*
2. Icebreaker exercise using audiovisual montage - *sensory elicitation*
3. Asking law enforcement about their job in general and different enforcement activities that they are engaged in – *focus group*
4. The wider context of their job – the environment in which they operate and how they relate to birds – *focus group*

The questions in these stages were structured as follows:

1. **Icebreaker exercise- watching the audiovisual materials of the marketplace to elicit a sense of closeness to the marketplace and setting the scene / *latihan icebreaker- melihat dan mendengerkan rekaman audiovisual untuk memperoleh perasaan kedekatan kepada pasar dan memberi pemahaman awal.***

Participants were asked the following questions:

- What did you think of that? Any feelings or responses you would like to share please write on the board/flipchart / *Apa pendapat Anda tentang rekamannya? Apakah terdapat perasaan atau tanggapan yang ingin Anda sampaikan? Silahkan ditulis pada papan tersebut.*
- What is your experience watching the audiovisual materials? / *Apa pengalaman Anda dari melihat rekaman itu?*

2. **Asking law enforcement about their job in general and different enforcement activities that they are engaged in (what happens when they see a protected species, what is the process of species identification that they currently use)** / *Menanyakan penegak hukum tentang pekerjaan mereka dan berbagai aktivitas yang dilakukan sebagai bagian dari pekerjaan mereka*

- What three things are helpful for your job, and what three things could hypothetically make your job easier? Please write these thoughts on a sticky note and put them up on the board / *Sebutkan tiga hal yang dapat membantu perkerjaan Anda, sebutkan juga tiga hal yang mungkin jika tersedia dapat membuat pekerjaan Anda menjadi lebih* *baik/bagus? Silakan tuliskan pendapat Anda pada catatan tempel (sticky note) dan letakkan di papan tulis.*

- How would you feel if you were to discover a market trader who is selling endangered/protected species? / *Bagaimana perasaan Anda saat menemukan pedagang yang menjual spesies burung langka/dilindungi.*
- Follow-up: how would you feel to discover that this bird is now endangered in the wild? / *Bagaimana perasaan Anda ketika Anda tahu bahwa spesies burung itu sekarang hampir punah di alam?*

3. The wider context to their job – the environment in which they operate and how they relate to birds

- What do birds mean to you? / *Seberapa penting burung bagi Anda?*
- What do you think are the potential consequences of certain bird species going extinct? *Menurut Anda, apa dampak potensial kepunahan beberapa spesies burung di alam?*
- Do you think extinction is an important issue? / *Apakah Anda berpikir bahwa kepunahan adalah sebuah masalah penting?*
- Follow-up: How do you feel about this? / *Bagaimana perasaan Anda tentang hal ini*?
- Follow-up: Are you aware of any traded bird species that are threatened? / *Apakah Anda melihat ada spesies burung terancam yang dijual di sini?*
- Do you think popular songbird species are declining in Indonesia? / *Apakah menurut anda spesies-spesies burung di Indonesia semakin langka?* Follow-up: What are the reasons for the decline? *Apa yang menyebabkan kelangkaan tersebut?*

4. Narratives about technology in their work/CLE attitudes to technology and the use of technology in their job

- How do you currently identify birds you encounter in your work and how effective are these methods? / *Saat ini, bagaimana cara Anda mengidentifikasi burung yang Anda temukan di pekrjaan Anda, serta seberapa efektifkah cara tersebut?*
- If they do not currently use any technology: Why are you currently not engaging with any digital tools to do this? / *Jika mereka tidak menggunakan teknologi apapun saat ini: Mengapa saat ini Anda tidak menggunakan teknolog/alat/aplikasi digital apa pun untuk melakukan hal tersebut?*
- If they are using technology already for songbird identification: What does this technology do well and what does not work? If you could redesign existing technology, what techniques would you use? / *Jika sudah memakai teknologi untuk mengidentifikasi*

burung : Teknologi ini baik untuk hal apa saja? Apakah ada hal yang kurang bekerja dengan baik dengan teknologi ini? Jika Anda dapat mendesain ulang teknologi yang tersedia, teknik apa yang ingin Anda gunakan?

User-centred design sessions

5. **Feature Selection / Seleksi Fitur – Voting**
    - **List the features the team believes should be included in the product:** List all the features being considered, e.g., profile, connections with other agencies, feature selection to include with the basic species identification, chosen by voting. Example features include the IUCN status or the local and Latin names / *Daftar fitur yang diyakini tim harus dimasukkan ke dalam produk: Daftar semua fitur yang sedang dipertimbangkan, misalnya: profil, koneksi dengan agensi lain, seleksi fitur untuk dimasukkan dengan identifikasi spesies dasar, dipilih melalui voting. Contoh fitur meliputi:*
6. **Feed the popular features from the feature selection/needs assessment into the Kano Model/Diagram.** Where do some of the features we've discussed rank in terms of impact and usefulness? / *Masukkan fitur populer dari seleksi fitur/penilaian kebutuhan ke dalam Model Kano/Diagram Kano. Di mana beberapa fitur yang telah kita diskusikan berada dalam hal dampak dan kegunaan?*

7. **Wireframes/Black Hat Session:** Show the wireframes in paper form, stuck onto a board – known as a low-fidelity prototype. On the wireframe examples from above, or critique of an Android application, what steps are missing? Where are the developers' assumptions wrong? Is a mobile application the best way to use a technology like this? / *Wireframes/Sesi Topi Hitam: Tunjukkan wireframes dalam bentuk kertas, ditempelkan pada papan – dikenal sebagai prototipe fidelitas rendah. Pada contoh wireframe di atas, atau kritik aplikasi Android, langkah apa yang hilang? Di mana asumsi pengembang salah? Apakah aplikasi seluler adalah cara terbaik untuk menggunakan teknologi seperti ini?*

Guide 2: Interview structure and script (a selection of questions relevant to this paper, part of a broader interview on experiences visiting wildlife marketplaces and bird trade) for discussions with academics and conservation organization staff for the purposes of triangulating the focus group data.

PERSON EXPERIENCE VISITING WILDLIFE MARKETPLACES

1. How often do you go to markets?
2. Since what year, when was the first time you ever went to one?
3. How many wildlife markets have you ever been to in your life?
4. And if species do go extinct from trade, what do you think is the impact on bird trade or bird keeping practices?
5. in terms of sustainability and welfare aspects of trade, what's your experience of this and your opinion on the state of trade relating to mortality and welfare issues?
6. How do you feel about keeping birds in cages?
7. What is the future of bird trade in Indonesia?
8. What do you personally feel and what do you think is, is realistic or achievable?

TRADE CHAIN AND THE STATUS IN GENERAL

Enforcement within the trade chain

9. Do you think the current methods of law enforcement for songbird's work? So, this could be like the law itself, or activities related to the law (or more generally about the effectiveness of the law, for example)
10. How do you think bird trade should be enforced, in an ideal world?

IDENTIFICATION

11. How would you describe your identification capabilities?
12. What methods if any, do you use for species identification?
13. What helped you get better at identification?

Appendix D – Chapter 3

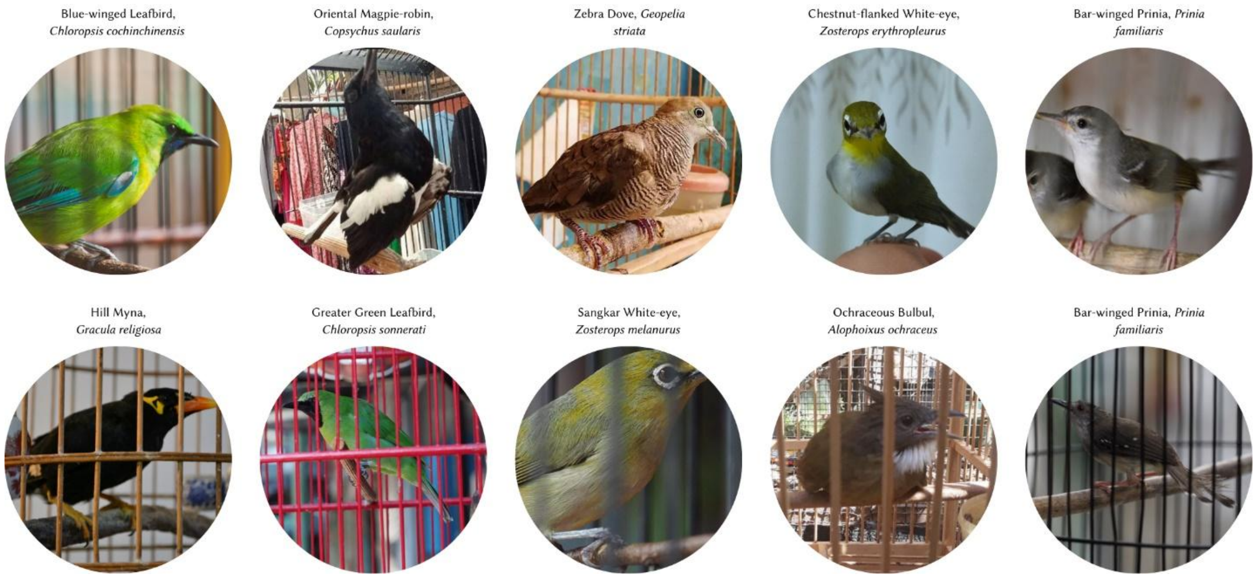

Figure D1: *Images of the 10 species discussed with law enforcement officials to assess species identification capabilities. The species were chosen based on their seizure volume from Indraswari et al. (2020) and their popularity in singing competitions and owners and ownership. Laminated visual aids facilitated discussions, including examples of genera known for look-alikes, such as leafbirds (Chloropsis) and white-eyes (Zosterops).*

Appendix E – Chapter 4

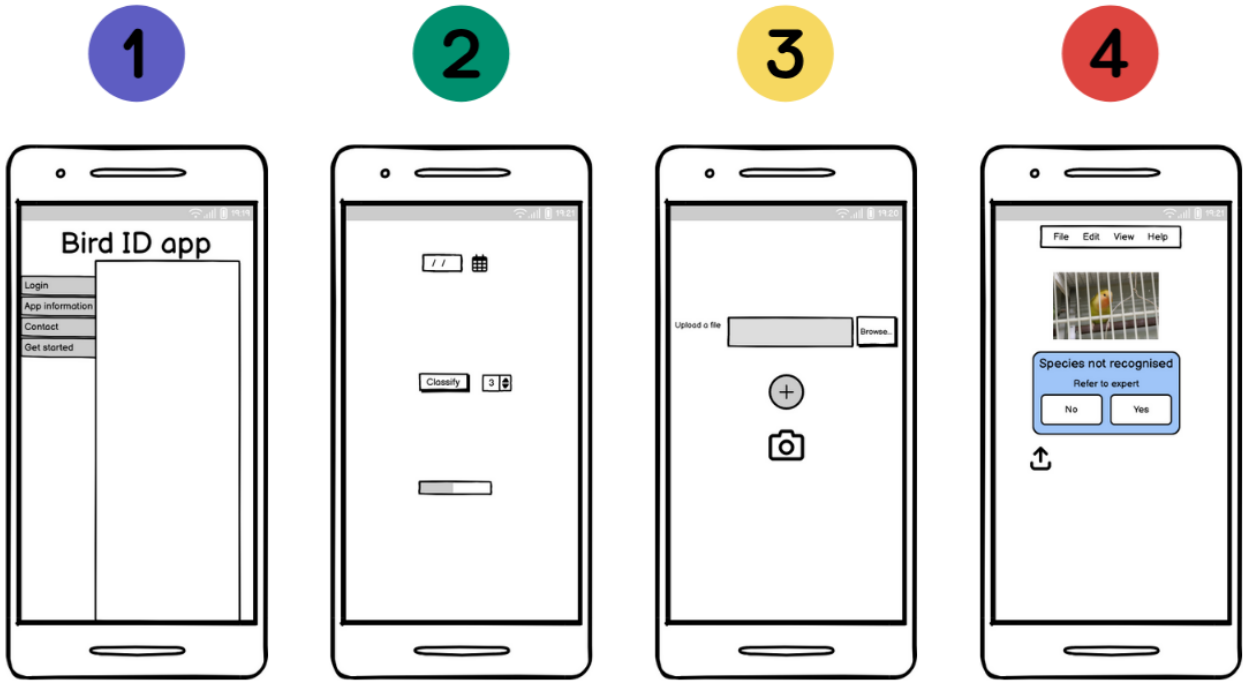

Figure E1*: Wireframe for a hypothetical bird species identification tool pre-session with Indonesian conservation law enforcement (made in Balsamiq).*

Appendix F – Chapter 6

Table F1*: Comparison of the specifics of the Five Freedoms and the Five Domains Model. Reproduced from Sopel (2021).*

The Five Freedoms	**The Five Domains**
1. Freedom from hunger and thirst	1) Nutrition- sufficient, balanced, varied and clean food and water
2. Freedom from discomfort	2) Environment – comfort through temperature, substrate, space, air, odour, noise and predictability
3. Freedom from pain, injury and disease	3) Health – enabling good health through the absence of disease, injury and impairment with a good fitness level
4. Freedom to express normal behaviour	4) Behaviour – providing varied, novel and engaging enrichment through sensory inputs, exploration, foraging, bonding, playing, retreating and others
5. Freedom from fear and distress	5) Mental state – the animal should benefit from predominantly positive states, e.g., pleasure or comfort, whilst reducing negative states such as fear, frustration, hunger, pain, or boredom

Table F2: *Violations of the five domains towards birds in trade noted in the literature and hypothesized differences between the wild and captive lives of birds.*

Domain	**Example**
Nutrition	Some birds change colours in the marketplace, the Javan Green Magpie, *Cissa thalassina,* goes from green to blue from a lack of lutein (a yellow-colored pigment found in fruits, vegetables, and eggs) in its diet (Van Balen et al. 2013)
	Lack of food and/or water in cages
Environment	As an example, the White-rumped Shama, *Copsychus malabaricus*, the territory is usually about 0,1 hectares (about 1.000 square metres). Area-wise, bamboo cages typically found in marketplaces are sometimes 30 x 30 cm; this is dramatically different from 1000 square metres.
	Migratory birds fly hundreds of meters high, none of which will be accommodated even by the highest aviary in the vertical sense.
	The harm birds may experience may also complicate their identification. For instance, their tails may abrade. Shorter tails are standard for birds in cages as the tail abrades really fast in the cage, and this is not a feature you can use in markets for identification (J. Eaton, pers. comms).
	In German bird markets, Bartels et al. (2022) also recorded a lack of or insufficient protection from weather conditions like solar radiation (similar to Vignette 3).
Health	At Pramuka market, we saw broiler-style crates, which can cause osteoporosis in hens due to cramped conditions and lack of exercise, making their bones prone to breaking (Peng and Broom 2021). Nijman et al. (2022) found that these plastic crates were also used to transport Wandering Whistling-ducks, *Dendrocygna arcuata*, from Lake Jempang in Kalimantan, without room to move or access to food or water, for 15 to 20 hours by road, regularly violating basic welfare provisions.
	In May 1994 at Pramuka bird market, a bird offered as a Critically Endangered Bali myna was actually a Black-winged Myna, *Acridotheres melanopterus* with its yellow eye-patches colored blue (Nijman et al. 2021)
	Ferns (2017) also recorded dead and decomposing birds at the bottom of cages amongst the living birds in Sumatra marketplaces (Figure 1D)
Mental State	Birds, especially corvids, form strong social bonds and can experience grief. This suggests they might grieve the loss of their wild lives and social connections when in captivity (Dooren 2014).

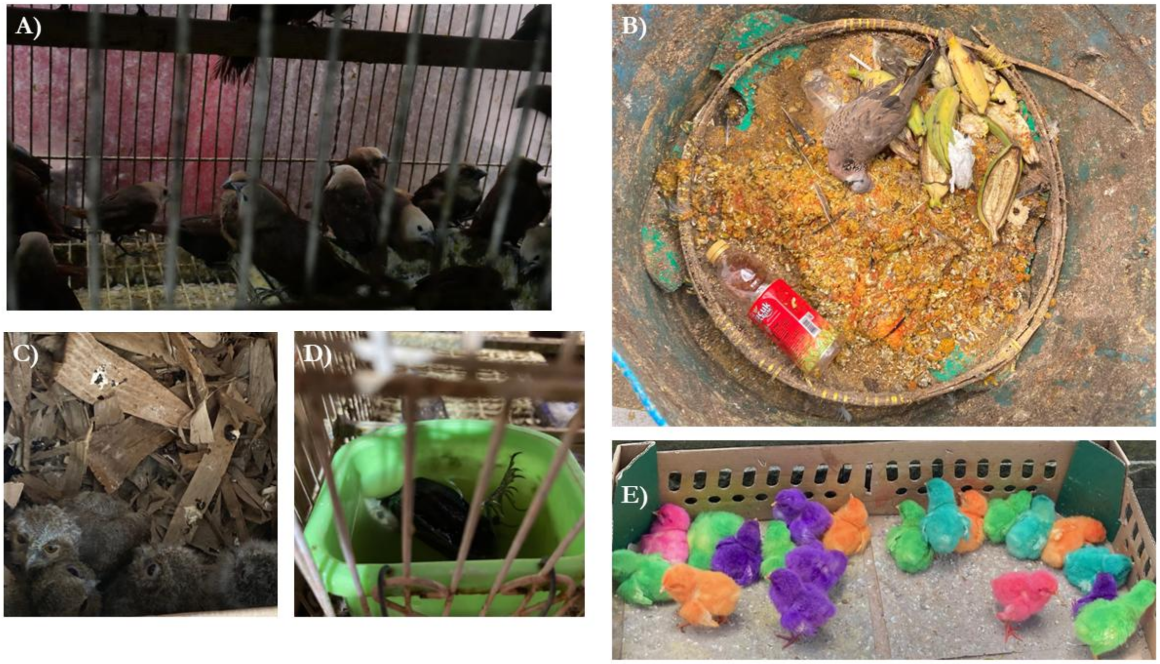

Figure F1: A) *White-headed Munias (Lonchura maja) experiencing overcrowding.* ***B)*** *Evidence of mortality: a dead spotted dove, with two warblers in the same bin underneath other rubbish.* ***C)*** *Sunda Scops-owlets (Otus lempiji) covered in or in close proximity to excrement***. D)** *A dead munia in a water pot,* ***E)*** *Baby chickens spray painted. Photos taken by the first author.*

Figure F2: *Blue-faced Honeyeater (Entomyzon cyanotis) observed in a marketplace, potentially transported up to 5,000 km (photo by Sicily Fiennes).*

Figure F3: *Other entities sold at wildlife marketplaces as multispecies communities;* ***A)*** *forest cats,* ***B)*** *civets and long-tailed macaques,* ***C)*** *live insects to feed insectivorous birds and* ***D)*** *flying squirrels. Photos taken by Sicily Fiennes.*

Table F3: *Evidence from interviews (and the literature) for human trade actors. Role references are included in the column. In the role section, if a name comes from existing literature, it is referenced. Otherwise, terms were used by interviewees or conservation law enforcement officers.*

Stage	**Role**	**Quotes**
Harvester	Subsistence (Phelps et al. 2016)	Some people also hunt for themselves [for personal consumption] (ACL1)
	Opportunist (Phelps et al. 2016)	Opportunistic hunting reflects societal norms where capturing and selling wildlife, whether from forests or urban areas, is normalized. People commonly take something from their backyard to sell or make money from it (ACL1)
		In urban areas like Jakarta, people opportunistically catch birds, including escapees. They use traps with bait in high trees to capture species like barn owls, shamas, bulbuls, and shrikes, then sell them at markets or directly to buyers (ACL1)
	Rule abuser (Phelps et al. 2016)	Lasia and other islands adopted the practice, leading to the probable extinction of the Nias Hill Myna. Palembang and Javan traders introduced it, and now locals are continuing it (ACI1)
	Local guide (Phelps et al. 2016)	The locals had told us there were no more shamas left, as they had already caught them all. It seems the local island population learned these practices from Javan and city traders who visited and taught them (ACL1)
	Specialist commercial (Phelps et al. 2016)	The islands of Lasia and Babi were overrun by about 1,000 traders, who gathered at the same coffee shop. This attracted more people, leading to widespread bird trading. As a result, islands like Lasia and Nias adopted this practice, causing the probable extinction of the Nias Hill Myna and the depletion of shamas. (ACI1)
		With little left for dedicated trappers, small-scale efforts by local people are more common. They likely give birds to middlemen or local traders, such as bird shops in the capital town of Simeulue (ACI1)
	Recreational (Phelps et al. 2016; Marshall et al. 2020)	Maybe not just small businesses, more like a side hustle. Sometimes they give them away, keep them for a while, and then sell them later (NGOL4)
	Bycatch (Phelps et al. 2016)	In Java, particularly near markets like those in Bandung, small-scale hunters may catch birds in nearby forests, when they're hunting something else, and bring them to the market to sell (ACL1)
Intermediary	buying agents (Tsing 2015)	Middlemen go to the forest, pay local villagers to catch birds, and collect them through their own hunters. They receive orders from markets, consumers, or resellers, and then deliver the birds (ACL1, NGOL6)
	Couriers (Guciano et al. 2024)	Sometimes transporters are given vehicles by investors. As a smuggler, I would drive the car from Sumatra to Java, but the car is owned by the investor. I receive bribe money for this role (NGOL8)
		From Nusa Tenggara to East Java, birds are usually transported by trucks or ships with couriers, so they are not alone (GAKK-SUR-4)

	Dropshippers (penampung)(Basuni and Setiyani 1989)	There's another middleman who connects with buyers, including online shops and small-scale traders. The virtual trader can act as a physical marketplace, wholesaler, or sell specific types without a physical kiosk (ACL1, NGOL8)
		Trucks transporting birds from Sumatra to Java also supply stalls in Pramuka, either as orders or stock. There are several middlemen involved, and the birds are distributed to small-scale traders, kiosks, Pramuka, and online sellers (ACL1)
	specialist wholesaler	Trucks from Sumatra to Java follow a quota system and meet traders at locations like gas stations for bird drop-offs. These traders, referred to as middlemen, handle the distribution (ACL1)
		Middlemen send birds to a penampung (collector/gatherer), where they are collected in a warehouse before being packaged and shipped to Java (ACL1)
Vendors	door-to-door sellers (Jepson et al. 2011)	Seen on motorbikes at Sukahaji (First author), also NGOL6
	wholesalers	As the owner of CV. Aneka Burung, I sold a cockatoo to a seller at the Pramuka bird market. Additionally, I have colibris (sunbirds), which are very cheap and can be sold directly to hawkers or consumers (NGOL6)
	local shop owners (Jepson et al. 2011)	Seen in peri-urban areas in West Java and Kalimantan by the first author
	bird shop (kisok) owners (Jepson et al. 2011)	NGOL6
Consumers	Hobbyist (Marshall et al. 2020)	
	Contestant (Marshall et al. 2020)	
	Breeder (Marshall et al. 2020)	
	Affluent collector	Insight from authors

Table F4: *Methods for trapping and transporting birds from interviews and focus groups.*

Stage	Method	Shortened
Trapping	bird lime	Opportunistic trappers use birdlime, typically derived from rubber or jackfruit sap (ACL3, NGOI2, NGOL4). If the bird is smooth and not stuck in the birdlime for long, the damage is minimal, and its feathers remain smooth (ACL3, NGOL7)
		Birds caught using glue, adhesive, or birdlime often have damaged wings, they are not in high demand and don't fetch a good price (NGOL7)
		I don't know why they use birdlime; I think it's an old traditional method (NGOI2)
	mist nets	Mist nets are often used fishnets (NGOL7, ACL3)
		back in the day, when Chestnut-capped Thrushes were trapped a lot in the lesser Sundas, the guys used to stick up mist nets about 200 metres long. Mistnets are definitely the most common (NGOI2)
		they'll [harvesters] just stick 20 metre poles either side [of the net] and then just stick it up… they put it in the breakaways between the trees, in clearings, over roads (NGOI2)
		Mist nets are quite expensive, costing around USD 50 (NGOI2)
	canopy mist nets	Trappers use canopy nets to catch entire flocks, which has increased the trade of canopy species like minivets and nuthatches (NGOI2)
	fish hook	hooks, fishhooks (NGOL4)
	bird to scare off	But I think people are more often using owls to attract. Yeah, and other birds to sort of, to then scare the owl off. You might get a mixed flock coming in to sort of sort of do it or whatever (NGOI1)
	poison	termites on the hook (NGOI1)
	baited cages	They set up cages in the canopy with fruit to trap Hill mynas, using a rope to hoist the open cage. I'm unsure how effective this method is (ACI1)
		Hunters typically use traps with trails that birds follow, leading them to get trapped (BKSDA_4)
	playback lures	That's created a massive problem online, Sound Recording libraries… are now restricted, but it didn't always used to be like that' (ACI1)
	decoy birds	A singing male bird attracts another for a contest in the forest. Hunters use a two-cage system, placing a male from their collection on the ground to attract another male or a mate. This creates a natural competition, aiming to capture a wild male. The cage is modified to close when the bird enters to eat the food (NGOL4)
Transport	woven palm leaf pouch	Birds can be brought to hunters in leaf packages, specifically inside ketupat (woven palm leaf pouches). These are made when the bird comes from the hunter and is then taken to the middleman in the forest (NGOL5)
	socks	When my friends patrolled the forest, hunters used "kaos kaki" (socks) or fabric bags with strings to transport birds. They tied the beak with tape, wrapped the bird in fabric or newspaper to protect its wings, and fixed the legs to pre0vent breakage. They meticulously placed the birds in socks, tying and hanging them. One, two, three, four, five hanging there… (NGOL7)
	beaks tied with tape	When my friends patrolled the forest, hunters used "kaos kaki" (socks) or fabric bags with strings to transport birds. They tied the beak with tape, wrapped the bird in fabric or newspaper to protect its wings, and fixed the legs to prevent breakage. They meticulously placed the birds in socks, tying and hanging them. One, two, three, four, five hanging there… (NGOL7)

	cloth bags	The birds in the bag, like the shama bird or Oriental magpie-robin, are expensive and classy. They are rarely put in socks and are usually placed in small cages (5x5 or 10x10). The bags are rotated and modified. Hunters still use this method, packing the birds tightly so they remain silent (NGOL7)
		I think the cloth bag is most common when you go into the forest anyway. Yeah, you just sort of tied them off to your bag or whatever and dangle them (NGOI1)
	In shoeboxes	They used to transport the birds in shoeboxes, poking holes for air (NGOI2)
	watermelons	The bird might be repackaged or disguised in different ways. When it goes to the middleman and then to consumers, the packaging varies. Some use watermelons. Some use wire, sticks, and skewers to prevent sagging, with 5 to 10 birds inside. However, the birds become wet immediately (NGOL7)
	wooden cages	for expensive ones (ACL1)
		The birds in the bag, like the shama bird or Oriental magpie-robin, are expensive and classy. They are usually placed in small cages (5x5 or 10x10) (NGOL7)
	thermoses	One bird per thermos (NGOL7)
	plastic poultry crates	Observed by authors in marketplaces
	cardboard boxes	I saw two young traders posing with a ruffled female leafbird (possibly a blue-winged, Javan, or greater-green leafbird) that came from a cardboard box (Observed by authors in marketplaces)
Sale	cement bags	Observed by authors in marketplaces
	cages	Observed by authors in marketplaces
	plastic bags	Observed by authors in marketplaces

Figure F4: Birds traded in football-branded cages; ***A)*** *a canary, Serinus canaria in an FC Barcelona cage and* ***B)*** *a Crimson Sunbird, Aethopyga siparaja in an Arsenal cage.*

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Appendix G – Additional Outputs

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