Molecular approaches to reduce the illegal trade of shark and ray products in Indonesia

Thesis

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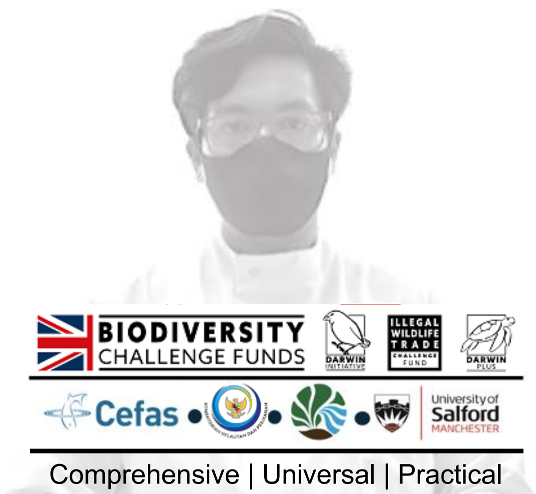

This thesis is presented to the University of Salford, School of Science, Engineering and Environment, in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD)

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"The seeking of knowledge is obligatory for every Muslim."

- Al-Tirmidhi, Hadith 74

Relevant works related to this thesis:

https://linktr.ee/dhika_fishery

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Acknowledgements

Salford, 29th June 2022 - My last pose in front of Peel Building at the University of Salford after being awarded the People's Choice in the 3MT presentation on SPARC 2022. Trust me, it was not a one man show, numerous amazing people allowed the man in this photo to stand (Courtesy by Holly Broadhurst).

Bismillahirrahmanirrahim - Manchester, 20th January 2019; the first day the tropical person from the down south country – Indonesia – stepped in England to pursue his dream. It all started back on August 10th, 2018 at 21:00 GMT+7 when I was interviewed by Stefano Mariani, Joanna Murray and Christopher Bird for the competitive Industrial Case Award Funded PhD Studentship in which I was currently conducting shark and ray market research in Aceh. The position was offered to investigate shark and ray trade and to improve trade monitoring using genetic-based approaches in my home country. As the approaches was relatively new for me, it scared me and made me doubtful about myself and how I will finish the next 4 year journey. Story in short, mid-2022 I handed in my thesis to be examined, so I must acknowledge the individuals who made it all possible, from whom I learned many things and will be eternally grateful.

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Permits

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Abbreviations

CITES	:	Convention on International Trade in Endangered Species of Wild Fauna and Flora
FAO	:	Food and Agriculture Organization of the United Nations
HS code	:	Harmonized System (HS) codes
IUCN	:	International Union for Conservation of Nature
CoP	:	Conference of the Parties
NDF	:	Non-detrimental Findings
FMA	:	Fisheries Management Area
MMAF	:	Ministry of Marine Affairs and Fisheries Republic of Indonesia
RFMOs	:	Regional Fisheries Management Organizations
B/LPSPL	:	Balai/Loka Pengelolaan Sumberdaya Pesisir dan Laut - Institute for Coastal and Marine Resource Management
AFQQI	:	Fish Quarantine and Inspection Agency
DNA	:	Deoxyribonucleic acid
PCR	:	Polymerase chain reaction
Real-time PCR	:	Real-time polymerase chain reaction
qPCR	:	Quantitative polymerase chain reaction
LAMP	:	Loop-Mediated Isothermal Amplification
NGS	:	Next-generation sequencing
eDNA	:	environmental DNA
BS1	:	Barcode segment 1
BS2	:	Barcode segment 2
MIC	:	Magnetic Induction Cycler
COI	:	Cytochrome c oxidase I
HTB	:	high throughput barcoding
RMSE	:	Root Mean Square Error
SNPs	:	Single nucleotide polymorphisms
MOTUs	:	Molecular operational taxonomic units
NCBI	:	National Centre for Biotechnology Information
RRA	:	Relative reads abundance
PERMANOVA	:	Permutational multivariate ANOVA
SRA	:	Short Read Archive

General Abstract

Trade restrictions have been established to counteract the rapid global decline of sharks and rays (hereafter called elasmobranchs), such as controlled species under CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). This has resulted from high fishing pressure, by-catch and market demand for certain products (e.g. fins). Tackling the illegal trade of endangered species poses enormous challenges for authorities, including taxonomic ambiguity, product variety, logistical issues for inspections and trade flow complexity. Based on extensive trade statistics, we found there was a substantial mismatch between exports of elasmobranch fin and meat products and the corresponding figures reported by importing countries ($43.6 M and $20.9 M for fins and meat, respectively) from the top shark landing country; Indonesia. That may signal illegal trading activities. When key visual identification for shark products disappears, genetics tools may help to improve trade monitoring. Over 579 tissue samples were collected in many locations (export hubs, processing plants, collectors, authority offices and landing sites) across Java Island, Indonesia, which have diverse processing conditions. Portable genetic techniques are urgently required to improve traceability, and we tested a recently developed universal assay (known as FastFish-ID) based on real-time PCR. By combining visual and deep learning assignment methods, we were able to successfully validate the method on 25 out of 28 species, 20 of which were CITES-listed. However, the illicit trade may be concealed from inspection, and that is a challenge for individual tissue-based genetic approaches. The 'shark-dust' metabarcoding approach offers an innovative application of metabarcoding to reveal the diversity of sharks being traded only based on the processing residues. This stupendous technique revealed 27 more taxa than individual tissue-based techniques and found that over 80% of the reads belonged to CITES-listed species. We argue that these approaches are likely to become a powerful, cost-effective and applicable monitoring tool wherever marine wildlife is traded globally.

Keywords: trade monitoring, conservation, CITES, sharks, rays, lab-on-the-field, portable tool, DNA metabarcoding, environmental DNA, Indonesia

Chapter 1
General introduction

Figure 1.1. Specimens of guitarfishes and wedgefishes were initially identified during tissue sample collection in Tegal Fishing Port, Central Java, Indonesia (Courtesy of Marine Cusa).

1.1. Shark and ray utilization

1.1.1. Global status of shark and ray population

People obtain benefits from ecosystems (biotic and abiotic entities), which includes the provisioning of services, non-material benefits and regulating services; collectively these benefits are called ecosystem services (MEA, 2005). However, in an effort to extract these benefits, we often forget that landscapes produce multiple ecosystem services at the same time that interact in complex and dynamic ways (Bennett et al., 2009). The massive disturbance to these systems affects natural biodiversity and unbalances the natural system, including biodiversity loss. Biodiversity loss is the loss of biological diversity caused by an inflated extinction rate for different species. Many disturbances to biodiversity are irreversible due to the nature of species and the level of disturbances, which has now resulted in a biodiversity crisis (Bradshaw et al., 2021). Since agriculture began 11,000 years ago, the biomass of terrestrial vegetation has been halved (Erb et al., 2018), with a loss of >20% of its original biodiversity (Díaz et al., 2019). This means that over 70% of the Earth's land surface has been transformed by humans (IPBES, 2019). Over the past 500 years, >700 vertebrate (Díaz et al., 2019) and 600 plant (Humphreys et al., 2019) species have gone extinct, with many more unrecorded (Tedesco et al., 2014).

The ocean ecosystem is also inextricably linked to these catastrophic events. Human activities have had a negative impact on more than two-thirds of the world's seas (Halpern et al., 2015). During the UN "Decade of Biodiversity" from 2011 to 2020, states promised to increase human welfare and food security by protecting ecological services and ending biodiversity loss (Brooks et al., 2015). The Sustainable Development Goals, endorsed by all UN member states, and the 20 Aichi Biodiversity Targets, gave a framework to assess progress toward 2020, including securing long-term benefits for “Life Below Water”. However, wild-caught fisheries are significant nutritional and economic resources for millions of people worldwide (Hicks et al., 2019, FAO, 2020) and it is hard to measure changes in ocean biodiversity, ecosystem structure, function, and services (Pereira et al., 2012). These conditions raise concerns globally about the prospects of decelerating the risk of extinction for ocean-based species.

One of the most concerning is the dramatic depletion of sharks and rays (hereafter referred to as ‘elasmobranchs' (Dulvy et al., 2014, MacNeil et al., 2020)). Over the last half century (1970–2019), elasmobranch populations have declined by 71% (Pacoureau et al., 2021), making elasmobranchs the most threatened vertebrate lineage after amphibians (**Figure 1.2**). Elasmobranchs are one of the oldest and most ecologically varied vertebrate lineages, having originated at least 420 million years ago and swiftly expanding to occupy the apex of aquatic food webs (Kriwet et al., 2008). This group consists of numerous species which play a key role in coastal and oceanic ecosystem structure and function (Heithaus et al., 2012). Sharks and their relatives mature and reproduce slowly, with lengthy reproductive cycles and substantial maternal investment (Harry et al., 2022). Conservative life histories of many elasmobranchs result in poor population growth rates and inadequate densitydependent compensation in juvenile survival, making them susceptible to fishing mortality (Dulvy et al., 2014).

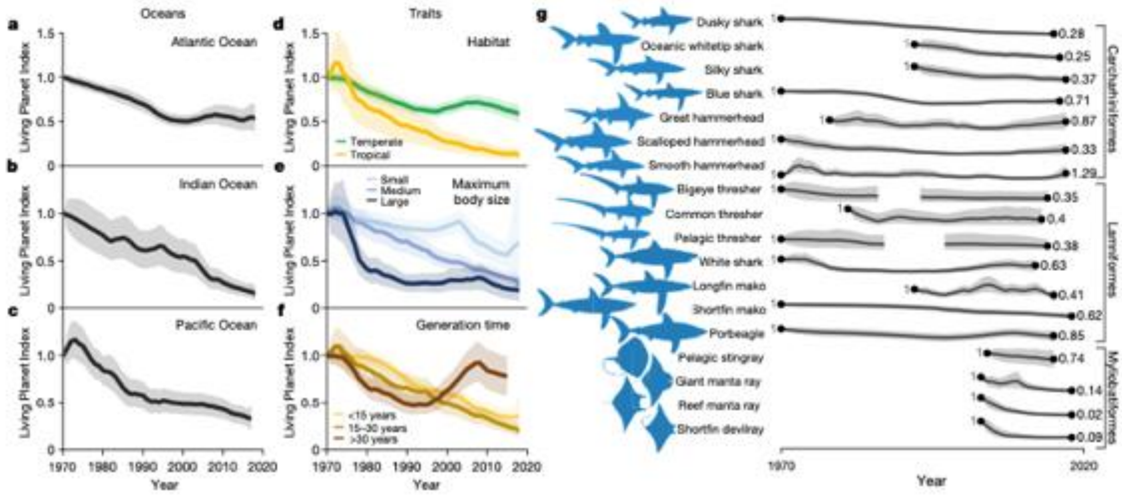

Figure 1.2. LPI for 18 oceanic sharks from 1970 to 2018 disaggregated for each of the oceans and traits. a, Atlantic Ocean; b, Indian Ocean; c, Pacific Ocean; d, geographical zone; e, body size (maximum total length divided into three categories: small, ≤250 cm; medium, 250–500 cm; large, >500 cm); f, generation time; g, species (the time-series for each species are shown in Extended Data Figs. 4–8). Lines denote the mean and shaded regions the 95% credible intervals (Pacoureau et al., 2021).

Elasmobranchs are commonly captured incidentally but are typically retained as valuable bycatch in fisheries that target the more profitable teleost species, such as tunas (Stevens et al., 2005, Wijopriono et al., 2019). Some elasmobranch fisheries can be sustainably managed (Simpfendorfer and Dulvy, 2017), but market demand for high-value products like fins, liver oil, and gill plates leads to overexploitation (Clarke et al., 2006, Dulvy et al., 2014). Unreported catches sustained by illegal trade further fuels overexploitation (Lo, 2020). Nearly 80% of recent captures were from the Atlantic Ocean and neighbouring seas (40%), the Pacific Ocean (33%, mostly from the Western Central region), and the Indian Ocean (27%) (Okes and Sant, 2019). Globally, approximately 7.4 million tonnes of sharks and rays were landed between 2010 and 2019 (**Figure 1.3**). Most elasmobranchs captured are commonly misidentified, unreported, aggregated, or thrown at sea (Simpfendorfer and Dulvy, 2017, Dulvy et al., 2014, Pacoureau et al., 2021) and may be associated with ineffective management measures (MacNeil et al., 2020).

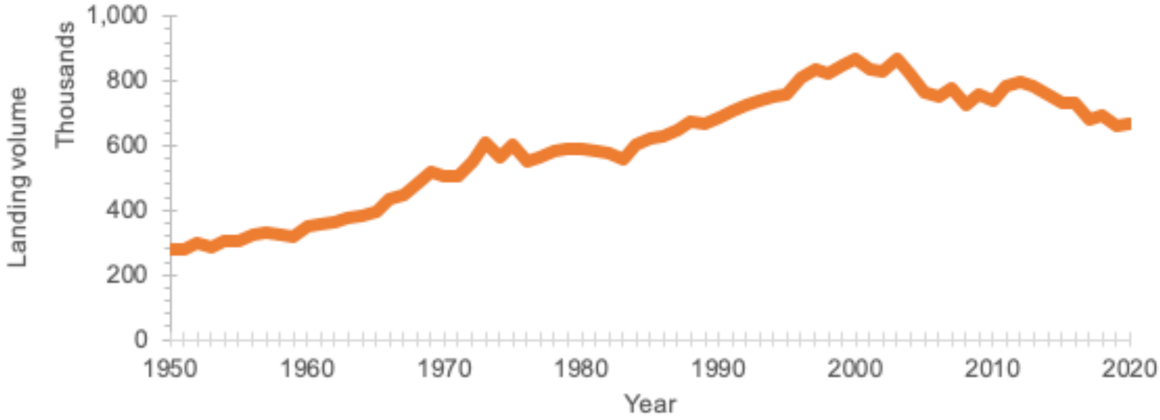

Figure 1.3. Global trend of shark and ray landing in 1950-2020 (FAO, 2022).

1.1.2. Shark and ray trade: Not only fins

Although elasmobranchs are primarily caught as bycatch, they have value in international markets, particularly for fin products. In addition, the demand for shark and ray meat has increased significantly in recent years. This high demand for elasmobranch products from the Asian market contributed to an increase in fishing pressure. Statistical data on landings and trade in shark and ray products is available for 1976-2019 from the FAO through FishStatJ (FAO, 2022). Within 10 years (2010-2019) almost 17% of total landings (1.2 million tonnes) was exported globally, which was valued at about $4,967 million (FAO, 2022, FAO, 2021) (**Figure 1.4**). During this period, 123,225 tonnes of fins and 1.1 million tonnes of meat products were exported, respectively. Those fin volumes were valued at $1,738 million, while meat was worth $3,219 million. Spain was the largest exporter of elasmobranch products, followed by Taiwan, Portugal and Indonesia in 8th position (**Figure 1.5a**). Those commodities were mainly headed to South Korea, Brazil and Spain, while fins products were imported mainly to Hong Kong (**Figure 1.5b**). From Hong Kong some portions of products have been re-exported to other countries (**Figure 1.5c**). Currently, international trade recognizes 12 Harmonized System (HS) codes; four codes belong to fin products while the other eight codes represent meat-based derivative products.

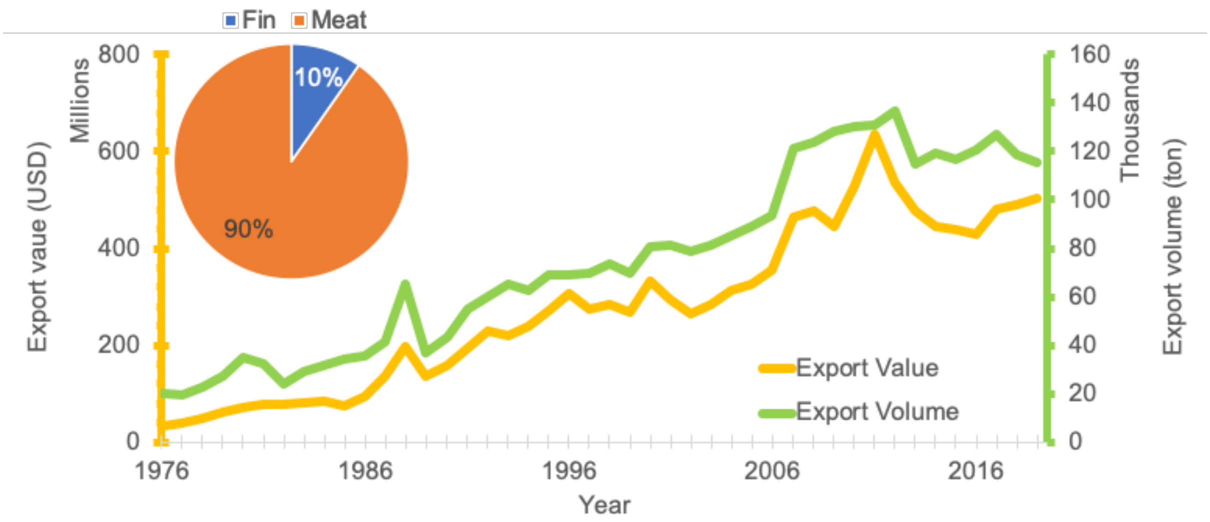

Figure 1.4. Global trend of export volume and value of elasmobranchs products and the composition of export volume shark and ray by commodities in 1976-2019 (FAO, 2021).

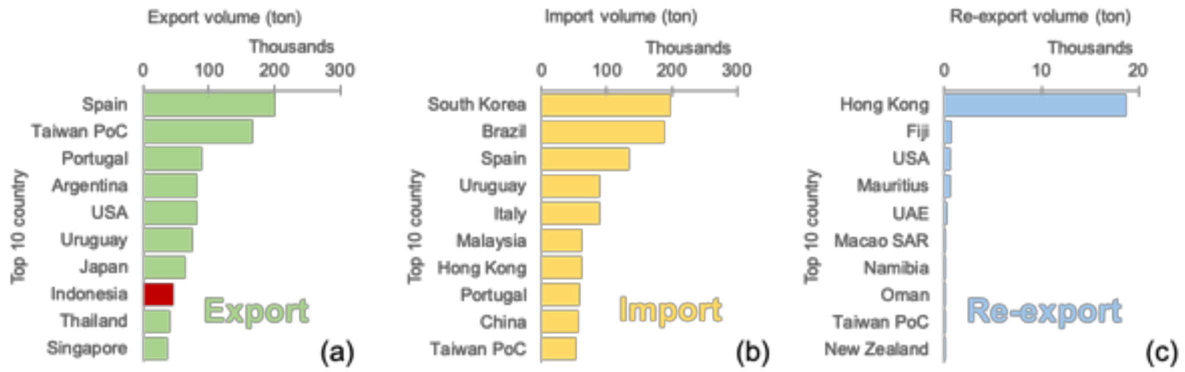

Figure 1.5. Top ten countries with significant trade flow of shark and ray products in ten years (2010-2019) sorted by export activities (a), import activities (b) and re-export activities (c) (FAO, 2021).

In a biodiverse ecosystem, depletion and exploitation require worldwide attention to establish effective measures to insure elasmobranch sustainability. This includes improving reporting, introducing regulations, and ensuring compliance, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) framework (Guggisberg, 2016). CITES is an intergovernmental agreement between governments. Its purpose is to ensure that the international trade in specimens of wild flora and fauna does not threaten the existence of the species. CITES was established after a 1963 IUCN decision (the World Conservation Union).

A gathering of 80 nations in Washington, D.C., on 3 March 1973 agreed on the convention's language, and it went into effect on July 1st, 1975. As the international trade in wild fauna and flora involves crossing jurisdictions between countries, international cooperation is required to protect particular species from over-exploitation. The protection is conducted by listing species that have a high degree of vulnerability into three appendixes i.e. Appendix I, II and III. In Appendix I are listed species threatened with extinction. The trade of products of these species is only authorized in exceptional conditions. Appendix II contains species that are not necessarily threatened with extinction but whose trade must be regulated in order to prevent a high risk of extinction. Appendix III indexed species are those where at least one nation has requested other CITES Parties for help in restricting trade. Each party may unilaterally alter Appendix III, unlike Appendices I and II. All imports, exports, re-exports, and sea-introductions of convention-protected species must be licensed. Each Convention Party must appoint one or more Management Authorities to manage the licensing system and one or more Scientific Authorities to advise them on the trade's impacts on species status. To date, it protects more than 37,000 animal and plant species, whether they are live specimens or processed commodities. In the early 2022, 47 of the 1,154 described shark and ray species are CITES-listed (Ebert et al., 2021, Last et al., 2016b). But since September 2022, through the 19th Conference of the Parties (CoP 19), the number of CITES-listed species has increased to 151 (CITES, 2022); yet, species listed in Appendix II can still be traded by considering the viability of exploitation within the Non-detrimental Findings (NDF) framework (Smith et al., 2011). Those additional listings will be effectively implemented in September 2023.

Understanding and regulating such trade is challenging because shark products are extremely diverse in both their usage and their value and are processed in a myriad of different ways (Dent and Clarke, 2015, Shea and To, 2017, Safari and Hassan, 2020). Depending on processing, shark products may not be recognized at the species level. Shark fins are the most popular shark commodity and are categorized into high-value and low-value fins based on size and species origin. Fins can be found in a variety of forms, from wet and dried unprocessed items that retain the original shape and skin to slightly chemically treated golden items that no longer display the original shape or morphological traits (Dharmadi et al., 2019b). Shark and ray meat are another common derivative product that is sold as fresh, frozen, dried or salted products. Other derivatives of elasmobranch products, such as gill racker, skin, liver oil, cartilage, are less prevalent and used in medicine, cosmetics and skin care products (Okes and Sant, 2019).

1.1.3. Shark and ray population in Indonesia

Several areas are elasmobranch hotspots, making them conservation priorities. Indonesia, with its many islands and diverse habitats at the interface between two ocean basins, is one such region, believed to harbour about 20% of global elasmobranch diversity (119 of 509 living sharks; 106 of 633 living rays), covering the whole spectrum of functional traits, from highly migratory oceanic species, to reef-associated, and sedentary bottom-dwelling coastal endemic taxa (Ali et al., 2014, Ali et al., 2018). The world's fourth most populated nation, substantial number of small-scale fisheries, illicit fishing, and unsystematic data collection make elasmobranch conservation management in Indonesia difficult. In Indonesia, 86% of the assessed fisheries catch elasmobranchs by accident or as bycatch. However, whole fishing communities target sharks exclusively, and in some cases only certain species, using specialized gear (Jaiteh et al., 2016, Booth et al., 2018). Indonesia was the highest contributor to worldwide elasmobranch landings during 2011-2020, averaging 105,100 tonnes each year (FAO, 2022) (**Figure 1.6**).

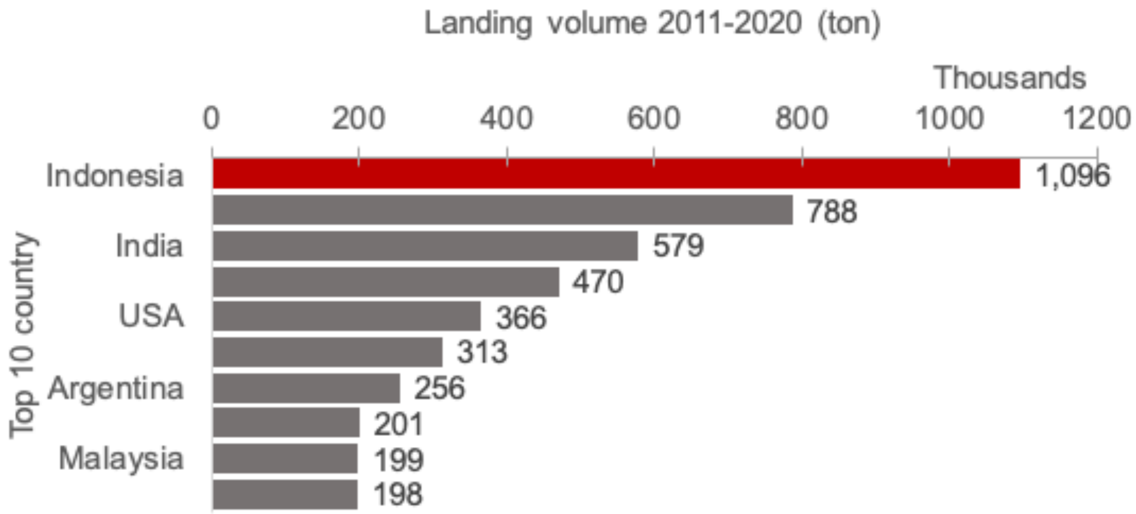

Figure 1.6. Top ten countries with significant landing volume of shark and ray from 2011-2019 (FAO, 2022).

Indonesian shark production data lacks species-specific taxonomic specificity. The Ministry for Marine Affairs and Fisheries (MMAF) groups landings into broad categories, such as requiem sharks (other Carcharhinidae) and thresher sharks (Alopidae). Moreover, Indonesia has 11 Fisheries Management Area (FMA) that overlap with provincial jurisdiction areas (37 provinces) (**Figure 1.7**). During the 2011-2020 period, nearly 1.1 million tonnes of sharks and rays were landed across Indonesia's 11 FMAs. FMA 711 (North Natuna Sea) and FMA 712 (Java Sea) were the major contributors, with 387,685 and 324,331 tonnes, respectively. Ray landings were substantially greater than shark catches in these two major areas (**Figure 1.8**).

Figure 1.7. Eleven Fisheries Management Area (FMA) as a baseline for fisheries management in Indonesia.

Figure 1.8. Activities in landing sites where sharks were caught by trammel net in Indramayu (a), unloading rays caught by trawler in Tegal Fishing Port (b), hand-line fishing fleet targeted sharks in Banyuwangi (c), auction hall in Tegal Fishing Port (d), night market at 11.00 pm in Muara Angke (e), thresher sharks landed and weighed in Cilacap Fishing Port (f) and artisanal fishing fleet in Palabuhanratu Fishing Port (g).

Within 10 years (2010–2019), the volume exported by Indonesia was insignificant compared to the total landing (FAO, 2022, FAO, 2021). Initially, sharks and rays were caught as by-catch and only valued for their fins. This was the time when shark-finning became common practice in fisheries (Dell'Apa et al., 2014), including in Indonesian fisheries (Jaiteh et al., 2017). However, with the growing demand for affordable protein, elasmobranch meat has become a food alternative (Clarke et al., 2006, Clark-Shen et al.). In some parts of Indonesia, elasmobranch meat is an important part of the local cuisine, i.e., Aceh (shark curry), Sibolga (salted shark), Tegal (shark satay) and Semarang (smoked ray) (Dharmadi et al., 2019a) (**Figure 1.9a-e**). Other body parts also have value and are processed into drugs (liver oil, cartilage, and gill racker), fish feed (intestine) and accessories (skin and teeth) (**Figure 1.9f-j**).

Figure 1.9. Other body parts of elasmobranchs have been utilized for local protein sources that are sold in the local market in Tegal (a), shark curry as local cuisine in Sibolga and Aceh (b-c), sliced and salted ray meat (d), shark and ray satay (e), shark oil in different quality (f), salted meat of shark for export (g), frozen blue shark meat for supplying superstores (h), fish feed from head parts of shark and ray (i) and tail of sting-ray for accessories (j).

In 2020, Indonesia formally had two management authorities. CITES-listing of terrestrial fauna and flora was under the jurisdiction of the Ministry for Environment and Forestry (MEF), while aquatic species that are listed in CITES appendices are managed by the Ministry for Marine Affairs and Fisheries (MMAF) with the B/LPSPL (Institute for Coastal and Marine Resource Management) as the implement agency across Indonesia's archipelago. To legitimate and accommodate additional CITES listings, MMAF issued Ministry Regulation No. 61/PERMEN-KP/2018 concerning the utilization of fish that are protected and/or listed under CITES appendices. MMAF also worked tirelessly to inform stakeholders about recent regulations, including strengthening collaboration with NGOs to reduce the impact of CITES regulations on communities. The huge volume of inspection, the archipelagic geography and limited resources (funding and money) add extra layers of complexity to monitoring elasmobranch trade (**Figure 1.10**). Those challenges to trade monitoring in Indonesia generated a disparity of trade statistics. Details of this phenomenon are analysed and discussed in **Chapter 2**. Despite the valuable efforts by the six B/LPSPL to meet the three main principles of CITES (legality, sustainability, and traceability) across the country, limited resources remain major challenges for authorities and exporters. Due to their similar appearance and the absence of visual keys, exporters might misidentify these species. This is where genetic techniques are useful when visual identification is difficult to counteract deliberate or unintentional mislabelling.

Figure 1.10. Condition of inspection and some derivatives products from shark and ray i.e. large volumes of mixed cartilages waiting for inspection (a), two containers full of dried shark and ray skin (b), inspectors checking a mixed bag of small fin and found some hammerheads fins (c), shark teeth (e), hardly processed ray skin (f), shredded fins ‘hissit’ in brine ready for exporting to Japan (g), blue shark cartilages soaked for processing (h), dried meat from small sharks (i), dried meat from large shark (j), live bowmouth guitarfish for aquarium market (k), and dried fins of silky and hammerhead sharks waiting for quota to export (l).

1.2. Wildlife forensic for improving trade monitoring

1.2.1. Non-molecular tools

There are extensive guides to identify whole sharks and rays globally (Last et al., 2016a, Ebert et al., 2021), the Southeast Asian Region (Ali et al., 2013) and Indonesian waters specifically (White et al., 2006). As monitoring CITES-listed species is urgent to tackle illegal trade, several visual guidelines were developed to identify shark and ray products, such as fins (Abercrombie and Hernandez, 2017, Abercrombie and Jabado, 2022c), full carcasses (Abercrombie and Jabado, 2022a) and processed carcasses (Abercrombie and Jabado, 2022b), including the iSharkFin-software designed to identify fin products of CITES-listed species (Barone et al., 2022). Species identification or verification of intensively processed items (fins, meat, liver oil, personal care products, skin and teeth) is more challenging. In many circumstances, DNA testing will be necessary to screen items randomly for unlawful trading or to validate or reject the identification of a product alleged to be derived from a CITES-listed species. DNA-based technologies are available to identify shark fins, flesh, and other traded items at different stages throughout the supply chain for CITES compliance and enforcement.

1.2.2. Overview of DNA-based tool in trade monitoring

Molecular approaches allow for the development of genetic-based identification where morphological features are no longer present (Ogden et al., 2009, Domingues et al., 2021). The arrival of DNA barcoding initiated standardized biodiversity assessments by focusing on a standardized fragment of COI from the mitochondrial genome (Hebert et al., 2003), which is conserved among vertebrate species (Ratnasingham and Hebert, 2007). DNA barcoding has been used to reveal seafood mislabelling and food fraud in various nations (Wong and Hanner, 2008, Miller and Mariani, 2010, Cawthorn et al., 2018). Mislabelling is a continuing problem for the seafood industry due to its detrimental economic and health effects on customers, who are likely unfamiliar with their seafood (Cusa et al., 2021). DNA barcoding has also been used to study the structure of elasmobranch populations and has been developed to tackle the illegal trade of elasmobranchs that are listed in CITES Appendices (Shivji et al., 2002, Hadi et al., 2020), the market for fresh specimens (Sembiring et al., 2015), and highly processed products (Fields et al., 2015) (**Figure 1.11**). The network showed that the general topic of DNA barcoding had associations with four generic clusters i.e. wildlife trade, product identification, species composition and phylogenetics. As the COI marker has been broadly used for DNA barcoding to detect endangered species in trade traceability, product detection was important for tackling mislabelling and ensuring food safety for human consumption especially when the products had lost their key visual identification. DNA Barcoding was also wildly used to investigate species composition in the ecosystem, next generation sequencing allows advanced DNA metabarcoding to monitor biodiversity from the traces organisms left behind in the environment (environmental DNA or eDNA). DNA barcoding was also particularly advantageous to assess species distributions, phylogenetics and reducing morphological ambiguities between species.

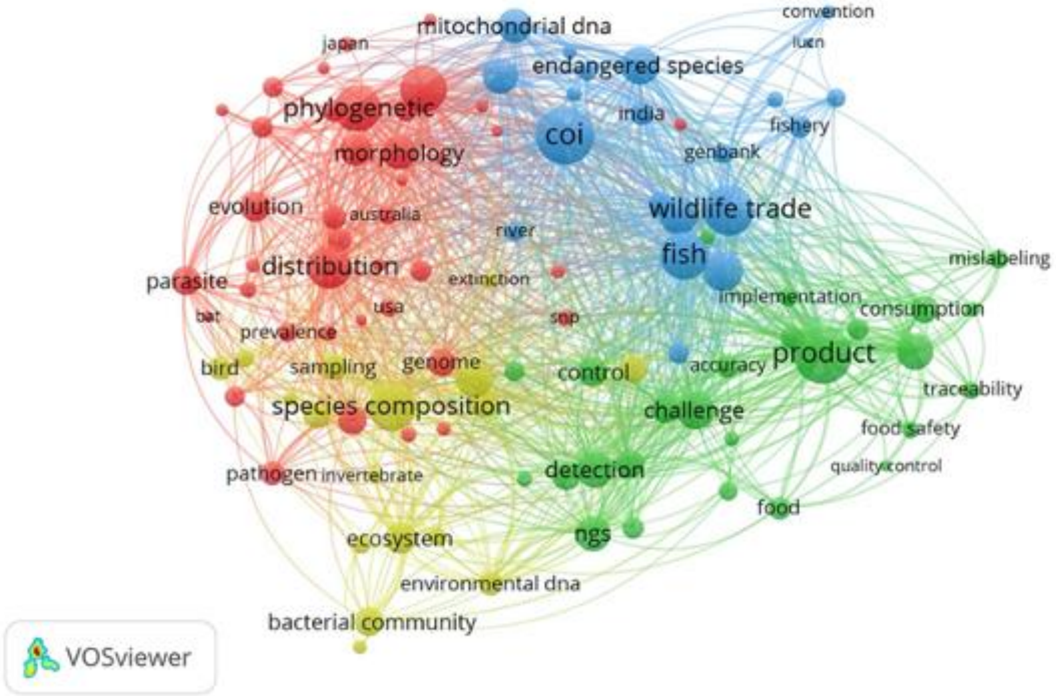

Figure 1.11. Network visualization for co-occurrence relationships between all keywords related to DNA Barcoding research that extracted from 3,000 articles published between 2005-2021.

However, all these methods require longer processing times and higher costs for their sequencing processes with recent advances PCR technology; a real-time PCR allow species identification to be conducted in the field by eliminating the sequencing stage. This technique was developed in general for DNA quantification (Klein, 2002) and pathogen detection of infectious diseases such as COVID-19 (Ferreira et al., 2021). During amplification, the real-time PCR uses fluorescent dyes and target-specific primers (such as DNA binding dye, hybridization probe, hydrolysis probe, molecular beacons, scorpions, sunrise primers, and LUX primers) to find the targeted nucleic acid template. This approach has been demonstrated to detect several CITES-listed species in a single run tube, such as the Multiplex real-time PCR assay to identify twelve CITES-listed species (Cardeñosa et al., 2018) and Multiplex LAMP to detect three CITES-listed shark species (Lin et al., 2021) using species-specific assays that reveal the species in a matter of hours. These approaches, however, are better suited to screening large numbers of specimens from a single species rather than analysing a wide variety of species. The recently developed universal closed-tube barcoding technology; FASTFISH-ID™, offers a potential solution to deal with the limitation of species-specific assays by developing universal probes with high flexibility of target sequences (Naaum et al., 2021). But this technology was originally designed for bony fishes (teleostei) and our research investigates the use of this technology for elasmobranch species (**Chapter 3**).

Recent developments in next-generation sequencing (NGS) have transformed generic DNA barcoding (Hebert et al., 2003) into DNA metabarcoding (Riaz et al., 2011). DNA metabarcoding simultaneously identifies multiple taxa based on short amplicon sequences from a single sample (Taberlet et al., 2018). These principles have been applied to the analysis of environmental DNA (eDNA) samples, which contain trace DNA fragments left behind by organisms in water, soil, and air (Ficetola et al., 2008) and have potential application to studying sharks and rays (Port et al., 2019). This method complements – and in some cases outperforms – traditional monitoring, particularly when labour and expertise are scarce, and has been used to examine elasmobranch biodiversity from water samples (Boussarie et al., 2018, Liu et al., 2021, Mariani et al., 2021). Such improvements enable bulk mixtures to be analysed and overcome conventional limitations of analysing specimens individually. In **Chapter 4**, we investigated the potency of DNA metabarcoding to enhance species detection to tackle illegal trade in the absence of individual tissue samples or those not visible at the time of inspection.

1.3. Overarching aims of the thesis

This study aims to investigate the trade flow of elasmobranch products in Indonesia and to advance molecular approaches to improve the detectability of sharks and rays. The investigation will examine the gap in trade activities and identify the patterns and drivers of the current scenario. As Indonesia has the largest volume of shark and ray landings in the world, trade monitoring is a challenge to Indonesia's authorities. Moreover, due to their similarity in appearance and lack of distinctive features in most derivative products, shark and ray species can be deliberately or accidentally misidentified by those involved in the trade. This has led to the rapid development of molecular technologies, which has progressively made DNA-based inference a staple of wildlife forensics. This research aims to examine possible molecular approaches that offer a universal, rapid and enhanced detectability of restricted shark products, such as close-tube barcoding (Sirianni et al., 2016, Naaum et al., 2021) and DNA metabarcoding (Taberlet et al., 2018). These tools will be developed with a high degree of reproducibility to be applied throughout the world. Ultimately, those efforts could save endangered shark and ray populations by tackling illicit trade (**Figure 1.12**).

Figure 1.12. Activities during fieldwork: airport check-in with 80 kg baggage (a), participant demonstrating DNA extraction using Biomeme™ (b), participants demonstrating how to do sample collection and preservation (c), taking a sample from LPSPL's collection in the hotel roof top (d), cold storage facilities in Muara Baru (e), collection of fresh samples in Tegal (f), sample preservation in hotel room (g), diced shark meat (h), shark and ray products in the local market (i), filming and documentation (j), interviewing fishers (k), frozen shark fins (l), demonstrating FASTFISH-ID in the processing plant in Indramayu (m).

1.4. Objectives

My main goal is to help ensure the long-term and equal benefits of elasmobranch resources both ecologically and socio-economically in Indonesia. Therefore, my PhD has the following broad objectives (**Figure 1.13**):

1. Chapter 1. To reconstruct the current status of Indonesia's shark and ray trade flow;
2. Chapter 2. To examine universal and rapid molecular identification methods of elasmobranch products; and
3. Chapter 3. To examine advanced DNA metabarcoding approaches to enhance detectability of restricted elasmobranch products.

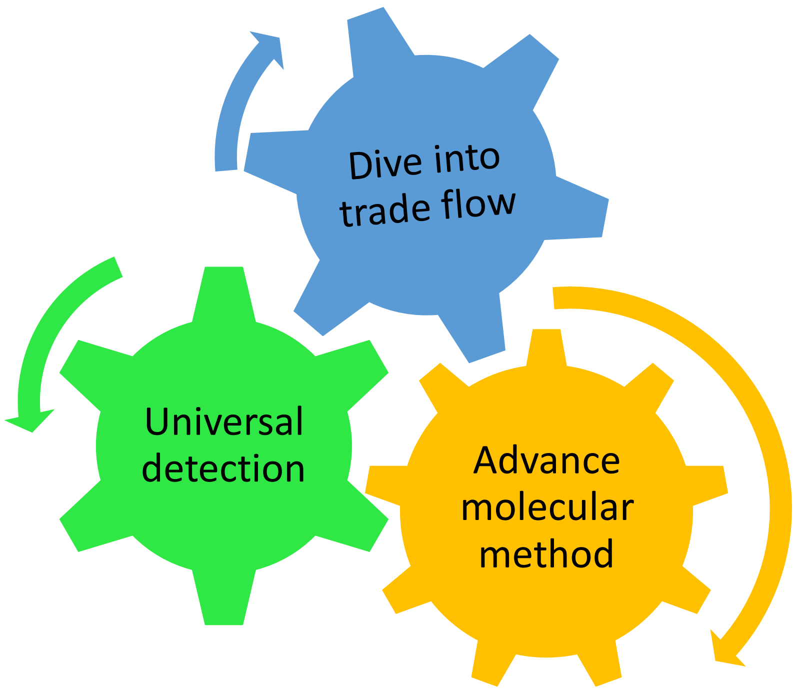

Figure 1.13. Research objectives of molecular approaches to reduce illegal trade of shark and ray products in Indonesia.

Additional information

Supplementary information

Figure S1.1. Research ethics no. STR1819-45 issued by Science and Technology Research Ethics Panel, the University of Salford, United Kingdom.

Figure S1.2. Research permit no. 251/BRSDM/II/2020 issued by Agency for Marine and Fisheries Research and Human Resources AMFRAD, the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

Figure S1.3. Export permits for CITES-listed specimens no. 00135/SAJI/LN/PRL/IX/2021 was granted under the authority of the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

Figure S1.4. Export permits for non-CITES-listed specimens 127/LPSPL.2/PRL.430/X/2021 was granted under the authority of the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

Figure S1.5. Import permit no. 609191/01-42 from the Animal and Plant Health Agency (APHA), United Kingdom.

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Chapter 2

Shark and ray trade in and out of Indonesia: Addressing knowledge gaps on the path to sustainability

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Figure 2.1. Susi, a third-generation traditional processor in Tegal processing smoked meat from various type of seafood, including sharks and rays to be sold to local market.

Abstract

Indonesian marine resources are among the richest on the planet, sustaining highly diverse fisheries. These fisheries include the largest shark and ray landings in the world, making Indonesia one of the world's largest exporters of elasmobranch products. Socio-economic and food security considerations pertaining to Indonesian communities add further layers of complexity to the management and conservation of these vulnerable species. This study investigates the elasmobranch trade flows in and out of Indonesia and attempts to examine patterns and drivers of the current scenario. We identify substantial discrepancies between reported landings and declared exports, and between Indonesian exports in elasmobranch fin and meat products and the corresponding figures reported by importing countries. These mismatches are estimated to amount to over $43.6 M and $20.9 M for fins and meat, respectively, for the period between 2012 and 2018. Although the declared exports are likely to be an underestimation because of significant unreported or illegal trading activities, we note that domestic consumption of shark and ray products may also explain these discrepancies. The study also unearths a general scenario of unsystematic data collection and lack of granularity of product terminology, which is inadequate to meet the challenges of over-exploitation, illegal trade and food security in Indonesia. We discuss how to improve data transparency to support trade regulations and governance actions, by improving inspection measures, and conserving elasmobranch populations without neglecting the socio-economic dimension of this complex system.

Keywords: elasmobranchs, conservation, Indonesia, mismatch, illegal trade, CITES

2.1. Introduction

The rapid depletion of sharks and rays (hereafter referred to collectively as just 'elasmobranchs') in many marine ecosystems is now recognized as a global conservation priority (Dulvy et al., 2014, MacNeil et al., 2020). Conservative life-histories (Mardhiah et al., 2019) make elasmobranchs vulnerable to fisheries overexploitation (ICES, 2016, Reynolds et al., 2005), which in turn can destabilise ecosystem structure (Sherman et al., 2020) and ultimately decrease global functional diversity (Pimiento et al., 2020). Overexploitation of elasmobranch resources is driven by a complex interplay between general expansion of global fisheries, with high-levels of elasmobranch by-catch, plus demand for high value fins from certain species (Clarke et al., 2006, Dulvy et al., 2014). Despite increasing regulations in international trade in recent years (e.g. under the Convention on International Trade in Endangered Species of Wild Fauna and Flora - CITES) high prices can create strong incentives for non-compliance (Challender et al., 2015a, Lo, 2020). Much of this trade involves poorly reported catches from Eastern and Western Pacific countries, which supply, for instance, global elasmobranch fin markets (Cardeñosa et al., 2020, Houtan et al., 2020). Understanding and regulating such trade is challenging because elasmobranch products are extremely diverse in both their usage and their value and are processed in a myriad of different ways (**Figure 2.2**) (Dent and Clarke, 2015, Shea and To, 2017, Safari and Hassan, 2020).

Figure 2.2. Storage, appearance and diversity (export commodities) of shark products: frozen shark trunks in cold storage (a), fresh rays landed in Indramayu, (c) ray cartilage, (d) stock pile of controlled species waiting for quota, (e) peeled shark fins, (f) shark oil, (g) peeled shark skin, (h) peeled ray fins, (i) “hissit” noodle-like from shark fins, and (j) shark salted meat.

A few regions of the world represent remarkable hotspots for elasmobranch diversity, making them focal targets for biodiversity conservation. Indonesia, with its many islands and diverse habitats at the interface between two ocean basins, is one such region, believed to harbour about 20% of global elasmobranch diversity (119 of 509 living sharks; 106 of 633 living rays). This diversity covers the whole spectrum of functional traits, from highly migratory oceanic species, to reef-associated, and sedentary bottom-dwelling coastal endemic taxa (Ali et al., 2014, Last et al., 2016, Ali et al., 2018). Indonesia is also the fourth most populous country in the world, with many communities traditionally associated with the sea (Foale et al., 2013). This makes elasmobranch conservation and management in Indonesia problematic, due to diverse and unregulated small-scale fisheries, high incidences of illegal fishing, and unsystematic data collection. Moreover, (Booth et al., 2018) reported that 86% of all Indonesian fisheries surveyed catch elasmobranchs incidentally or as by-catch. This occurs in both commercial and artisanal fisheries using various types of fishing gear, such as gillnets, longlines, seine-nets and trawlers. Most sharks caught as bycatch are from tuna longlines from commercial fishing fleets. In addition, whole fishing communities also exist that target elasmobranchs exclusively, and in some cases even certain species in particular, using tailored gear (Jaiteh et al., 2016, Booth et al., 2018). Between 2007-2017, Indonesia was the largest reported contributor to global elasmobranch landings, with a mean catch of 110,737 mt per year (Okes and Sant, 2019, FAO, 2020). The paired trends of depletion and exploitation – in such a biodiverse context – call for global attention to identify effective mechanisms to ensure sustainability of elasmobranch resources. This includes improving reporting, introducing regulations and ensuring compliance (e.g. through CITES) framework (Guggisberg, 2016) and other approaches (Booth et al., 2019a), with the ultimate goal of identifying a balance between preserving wildlife and sustainable resource use.

Globally, market demand of elasmobranch products is stable, especially fin products (Okes and Sant, 2019). However, since 2015, a dramatic increase was observed in the export of meat products in Indonesia (Niedermüller et al., 2021). This has been linked to emerging trammel net by-catch, as a consequence of the ban on shrimp trawling (MMAF, 2015). Much of these landings are believed to include vulnerable/endangered species, including several currently listed in the regulatory trade annexes of CITES. Since elasmobranchs are processed in many ways, this poses challenges to CITES requirements (i.e. legality, sustainability, and traceability) and other regulatory frameworks (Abdullah et al., 2020). The large amount of caught biomass, over a vast and diverse coastline, and the limited facilities and resources for inspection also add obstacles to effective monitoring of elasmobranch trade in Indonesia.

Elasmobranch conservation remains a high priority topic in marine ecology, but in many circles the focus is almost entirely on the goal of species conservation, with little emphasis on socio-economic aspects and limited evaluation of the trade-offs among the different stakeholders (Booth et al., 2019b, Iwane et al., 2021, MacKeracher et al., 2021). This study aims to reconstruct the current state of elasmobranch trade in Indonesia in order to lay the foundations for a remodelled management framework in light of socio-economic considerations for the world's most vulnerable marine vertebrate resources. To do so, we: i) collate and summarise data on landing trends, ii) investigate domestic trade flows, iii) examine import/export discrepancies, iv) identify factors, challenges and solutions to maximise ecological and socio-economic benefits.

2.2. Material and methods

National elasmobranch production statistics were compiled from 1950 to 2017, taking into consideration that fisheries data collection started improving gradually from 2005. In 2017, there was a significant change in national data collection operations, which included marine and fisheries sectors, which introduced the so-called "one-data" policy. This policy is designed to provide a regulatory framework and standard mechanisms to the principles of data interoperability among stakeholders (MMAF, 2017, Maail, 2018, MMAF, 2020). Currently, there is an improvement in data resolution through the addition of species-specific categories. This has been undertaken as a consequence of the binding resolutions of CITES and RFMOs (which require better data collection for species that are listed in their Appendices). This improvement in data collection is also mandated as part of the Indonesian National Plan of Action on Sharks and Rays, which was recently updated (2021-2025). It is important to note that, although the Ministry for Marine Affairs and Fisheries (MMAF) monitoring systems currently classify sawfishes as 'sharks', for the purpose of this study, we placed them among the rays, in line with their systematic classification (Batoidea:

Rhinopristiformes) (Last et al., 2016). Those official statistics were combined with the global capture production database from the UN Food & Agriculture Organisation (FAO, 2020) to provide a better insight of both national and international elasmobranch trade in Indonesia. We defined ‘controlled species’ as all sharks and rays that are listed in CITES’ annexes. Trade activities that fail to comply with national or international laws for such ‘controlled species’ are deemed ‘illegal trade’.

The domestic trade flow was examined by mining datasets from 46 fish quarantine offices across Indonesia, which included information about location of sources and destination, type of products, volume and estimated value (AFQQI-MMAF, 2019). The volume of domestic elasmobranch product exchange between source and destination locations was then plotted using the R package “network3D” (Allaire et al., 2017). To improve clarity, domestic trade was filtered to flows larger than 10 tonnes.

The elasmobranch import/export data were derived from the FAO Fisheries Statistics (FAO, 2019) and the Agency for Fish Quarantine and Quality Insurance (AFQQI-MMAF, 2019) over a seven-year period (2012–2018). This analysis period was selected because the FAO Fishery Commodities and Trade statistical collection (FAO, 2019) included elasmobranch import and export records only starting from 2012. ‘Export’ was defined as the product figures reported by Indonesia as traded out to other countries (‘partners’), while ‘Import’ represented the amount of produce that each trading partner declared as being imported from Indonesia (FAO, 2020). Data were then filtered by selecting i) type of trade flow (export, import or re-export), ii) source or destination country, and iii) harmonized system (HS) code (a code that consists of an internationally standardized system of numbers to classify traded products and commodities). Given the fluctuations in export and import value of fin and meat products, we estimated trade record mismatches by averaging the values between exports and imports over the whole 2012-2018. Bilateral trade flows between Indonesia and importing countries were represented using Circos (Krzywinski et al., 2009). The Circos graph allows for the data to be visualized into a circular layout and this is then used to explore the relationship between countries in this case. Calculations and visualisation were performed in R 3.6.1 (R_Core_Team, 2019). Discrepancy between Indonesia and bilateral trade partners were traced using the method detailed by (Cawthorn and Mariani, 2017) by subtracting the export figure reported by Indonesia from the corresponding volume reported by each partner country. The results were aggregated for the study period and for examined commodities, unless otherwise specified. Additional information about data sources can be found in Supplementary **Table S2.1**.

2.3. Results

2.3.1. Production statistics

Indonesia ranks as the world's top elasmobranch landing country in terms of quantity, while its imports are negligible. According to government production statistics, annual elasmobranch production has rapidly increased between the 1970s and 2000, becoming relatively steady over the past decade (2005-2014), oscillating between approximately 90,000 to 120,000 tonnes per year, with a 10-year annual average of 107,623 (SD 12,932) tonnes (MMAF, 2017, FAO, 2020, MMAF, 2020). Sharks generally amounted to just over half of landings, with the situation reversed in the last six years, when rays peaked to account for up to two thirds of reported catches in 2016 (**Figure 2.3**).

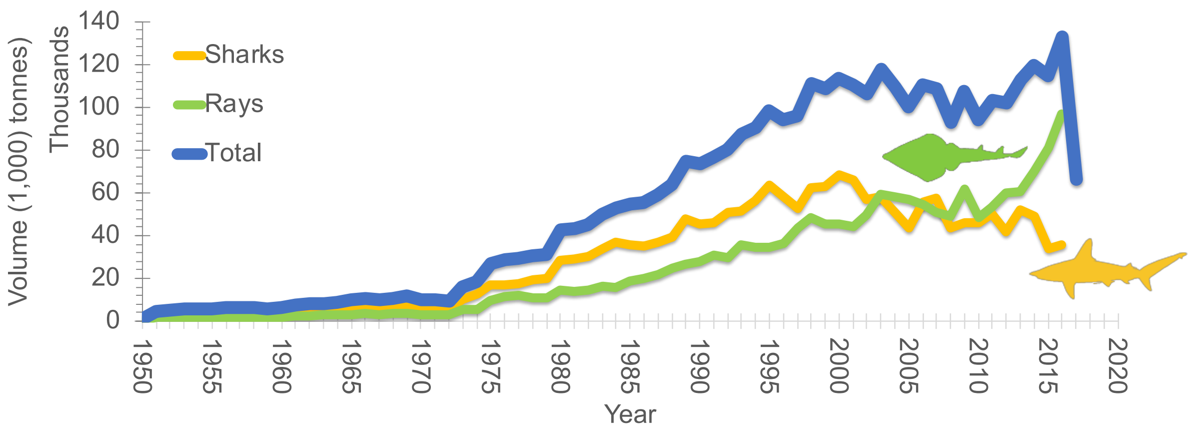

Figure 2.3. Volume of shark and ray landing in Indonesia 1950-2020. (MMAF, 2017, MMAF, 2020, FAO, 2022).

National statistics are grouped into broad categories (the official recording of nine and seven categories of sharks and rays, respectively), as collected by MMAF, e.g. requiem sharks (other Carcharhinidae) and thresher sharks (Alopidae) which made up most of the shark production over the past 14 years, contributing 51% and 22%, respectively (**Figure 2.4a**). Shark production from 2005 to 2018 fluctuated for each species group, but generally declined since 2016. Requiem (Carcharhinidae) and mackerel (Lamnidae) sharks have shown stable volumes over time. CITES-listed silky sharks (*Carcharhinus falciformis*) fall within the broader requiem shark group (other carcharhinidae), while tiger shark (*Galeocerdo cuvier*), oceanic whitetip shark (*C. longimanus*) and blue shark (*Prionace glauca*) were only recently put into separate categories in 2015. Stingrays (Dasyatidae) made up most of the ray production over the past ten years (56%), followed by wedgefishes (Rhinidae; 13%) and eagle rays (Myliobatidae; 8%). Ray production for most species has generally increased over time, although wedgefishes saw declines between 2005 and 2010 (**Figure 2.4b**). An increase of other rays since 2015 were generally dominated by the families of Gymuridae and Glaucostegidae.

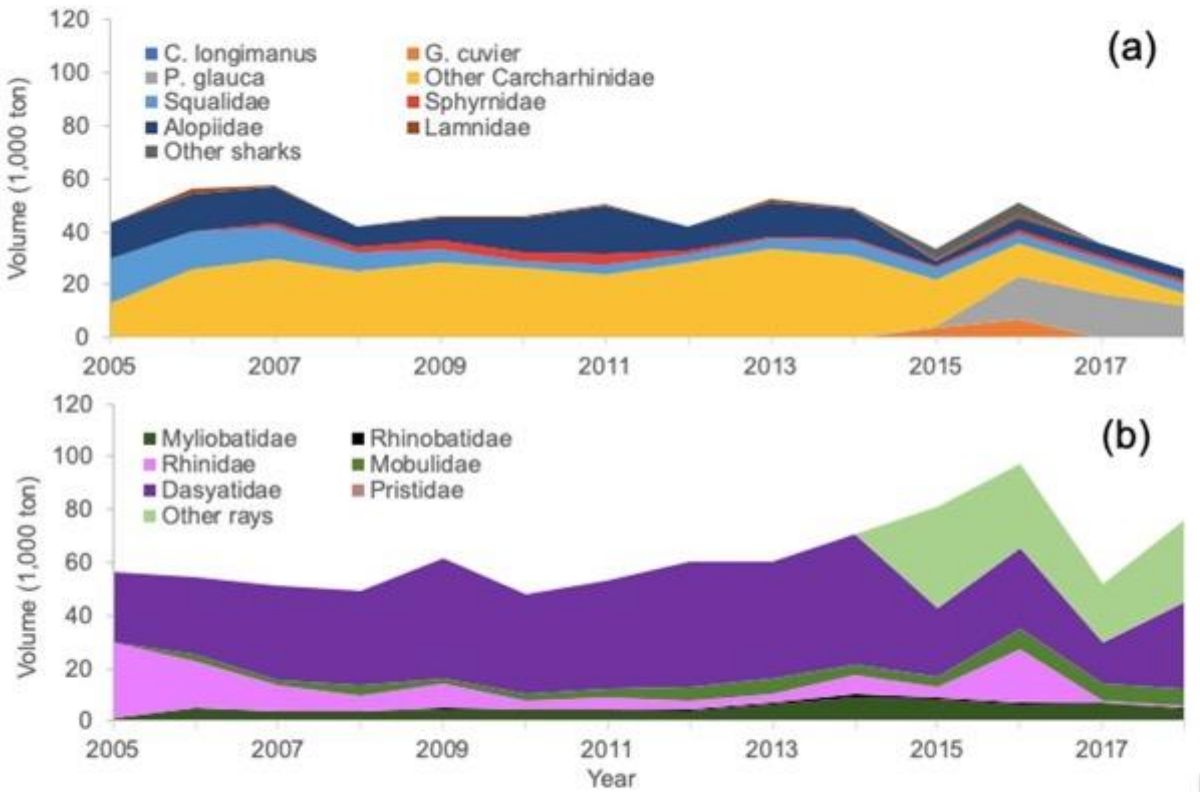

Figure 2.4. Sharks (a) and ray (b) landing and composition in Indonesia by species group 2005-2018 (MMAF, 2017, FAO, 2020, MMAF, 2020).

Indonesia has 11 Fisheries Management Areas (FMA) that overlap with provincial jurisdiction's areas (34 provinces). During the 2005-2018 period, nearly 1,488,006 tonnes sharks and rays were landed across Indonesia's 11 FMAs. FMA 711

(North Natuna Sea) and FMA 712 (Java Sea) were the major contributors, with 387,685 and 324,331 tonnes, respectively (**Figure 2.5**). In these two major areas, ray landings were substantially greater than shark catches. In those FMAs, tuna long-liners, gillnetters and trawlers were the dominant fishing gears (MMAF, 2020). Meanwhile, the volume of shark landings in the eastern part of Indonesia, such as FMA 714 (Banda Sea) and FMA 718 (Arafura Sea) were higher than rays.

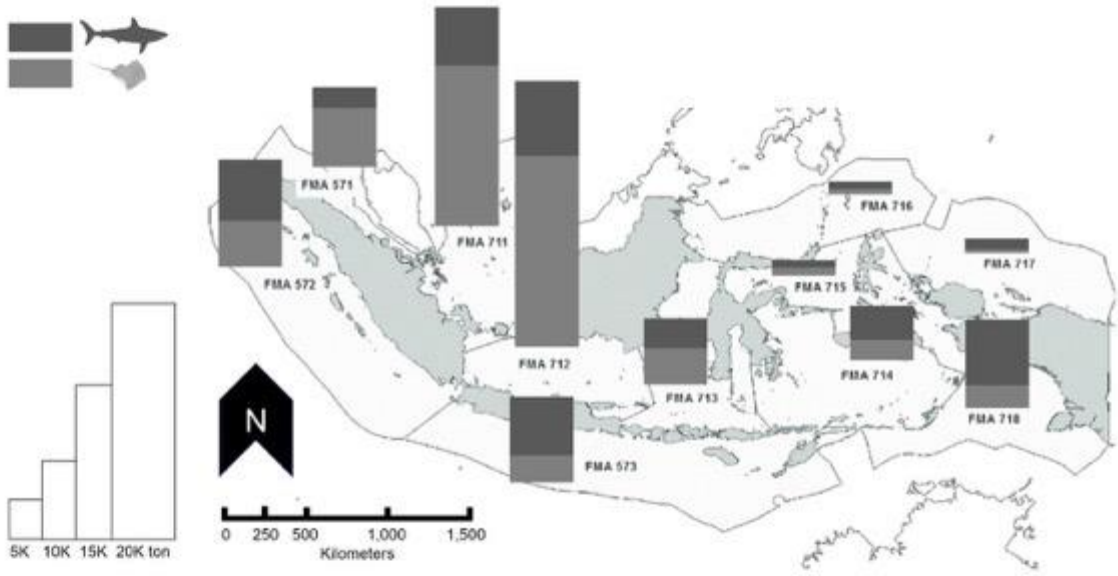

Figure 2.5. Cumulative volume of shark and ray landing by Fisheries Management Area (FMA) during 2005-2018 (MMAF, 2017, FAO, 2020, MMAF, 2020).

2.3.2. Domestic trade statistics

Based on national statistics, in 2018, the export of elasmobranch products was only just over 11.7% (11,867 tonnes) of landing data (101,707 tonnes), and only around 4% (30,560 tonnes) over the whole period between 2012 and 2018 (771,009 tonnes). As a large archipelagic country, even the internal supply chain is complex and involves several actors and transit locations. There are several main supplier provinces of elasmobranch commodities, such as Bali, Papua, West Papua, East Kalimantan and Bangka-Belitung Provinces (**Figure 2.6a**), with Bali and Papua together accounting for 68.2% of the outflow at 10,587 tonnes. The Bali province also plays a role as a transit hub prior to subsequent shipping to Jakarta and East Java Provinces (Surabaya) (**Figure 2.6b**), which are the two main international export hubs.

Moreover, these main suppliers were not mirroring the two main landing places located in the North Natuna Sea and the Java Sea. Additional information about domestic flow can be found in Supplementary **Table S2.2**.

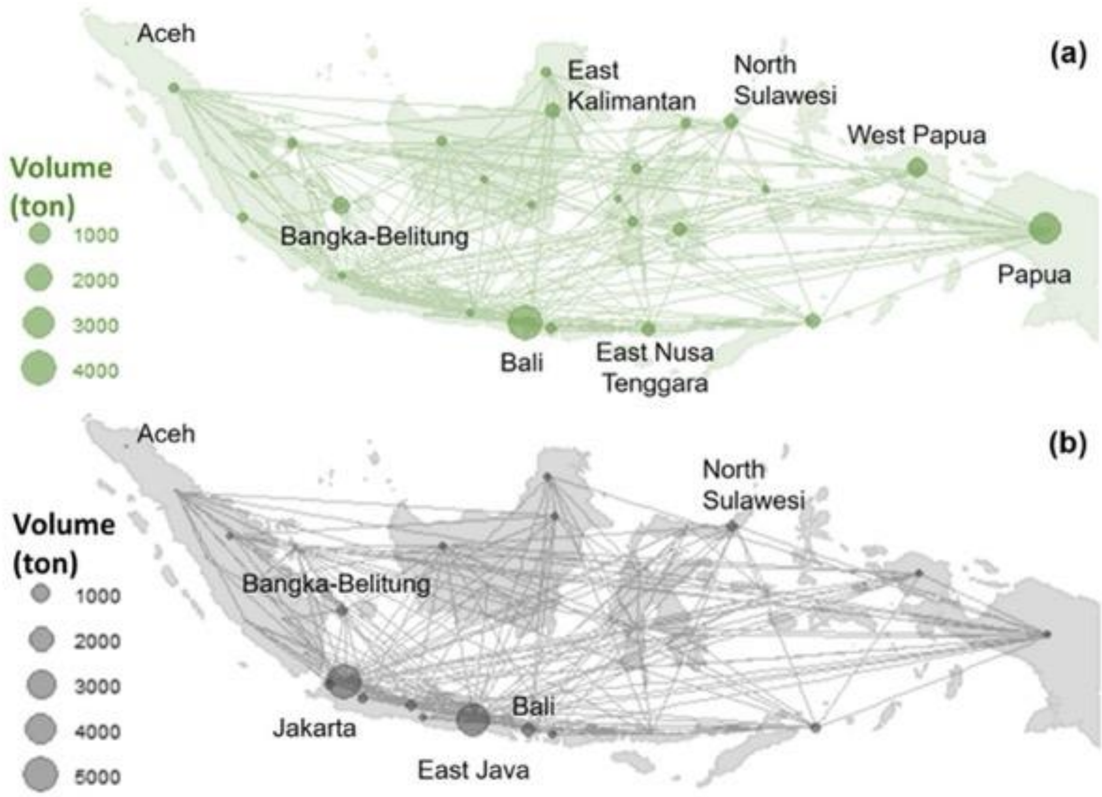

Figure 2.6. Domestic trade network of fin and meat products across Indonesia region within 2014-2018 (tonnes) by source (a) and destination provinces (b); provinces with label indicate significant contribution. (AFQQI-MMAF, 2019)

2.3.3. International trade statistics

Between 2013 and 2018, exported elasmobranch products increased steadily and reached a peak of 8,320 tonnes in 2017 (**Figure 2.7a**). Over 70% of the exported products are still dominated by meat, except in 2016, where the export of fins (878 tonnes out of 3,002) and cartilages (1,346 tonnes out of 3,002) was substantial (respectively 29% and 45% of the total). Indonesia also imported elasmobranch products, mainly the small-sized fins that are processed into *hissit* (shredded fins; noddle-like). However, the volume is negligible, amounting for just 155 tonnes throughout the 2012-2018 period. Products from the two main export hubs (Jakarta and Surabaya) were mainly shipped to Japan, Singapore, China and Hong Kong. In recent years, export of live elasmobranch has also increased steadily, almost doubling every year (**Figure 2.7b**) and are likely collected to supply the aquarium trade. This demand targeted the coral reef-associated species, such as black-tip reef shark (*Carcharhinus melanopterus*), zebra shark (*Stegostoma fasciatum*), bowmouth guitarfish (*Rhina ancylostoma*) and whitespotted whipray (*Himantura gerrardi*). The living elasmobranchs are mainly exported to China, Hong Kong, Malaysia and USA.

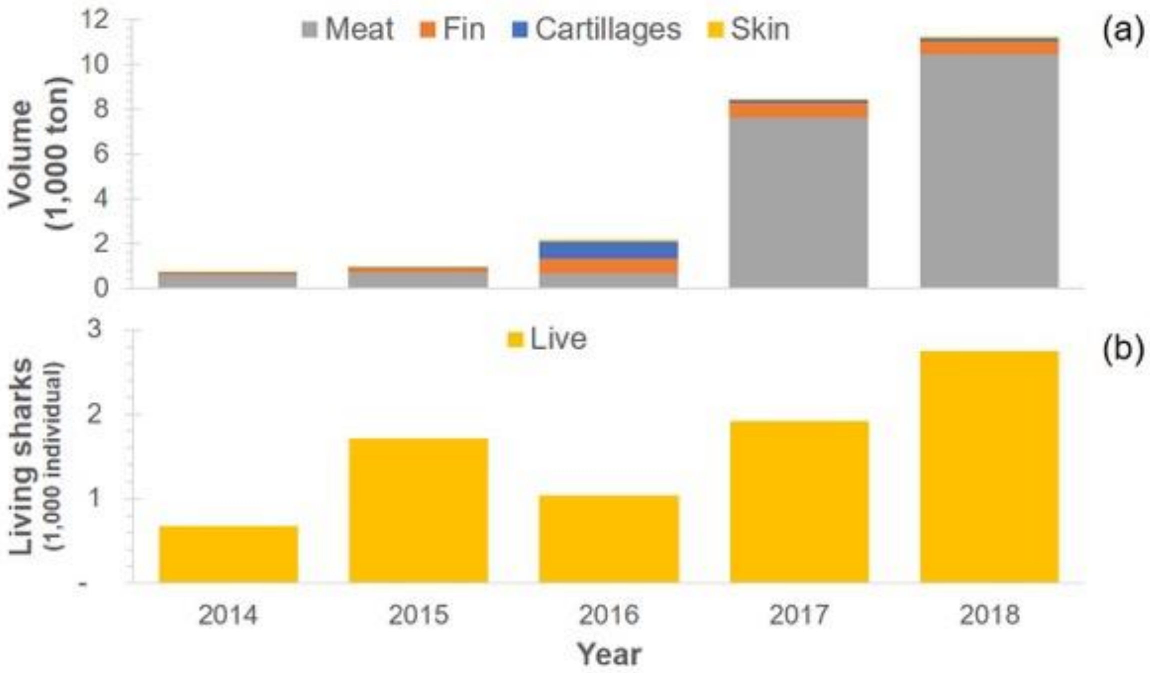

Figure 2.7. Export volume by products in 2014-2018 (a) and export for live sharks and rays in 2014-2018 (b). (AFQQI-MMAF, 2019)

We extracted export-import data from FAO Trade Statistics on elasmobranch products, from 2012 to 2018, treating ‘fins’ and ‘meat’ separately. We found a substantial level of misreporting in the fin trade (**Figure 2.8a**). In some cases, Indonesia reported less than what the importing countries declared (e.g. Hong Kong reporting 440.5 tonnes more than what was stated by Indonesia), and in other instances it was the importing partner reporting less incoming trade from Indonesia (e.g. Singapore declaring 521 tonnes less than what was recorded by Indonesia). Similarly, this phenomenon was also revealed in the meat trade (**Figure 2.8b**), with the notable case of Malaysia, which reports nearly 9,000 tonnes more incoming trade than what was shown by the Indonesian export records. On average, the discrepancy of fin and meat products were 54.4% (1,462 tonnes) and 47.1% (13,138 tonnes) of the export volume reported by Indonesia (2,689 tonnes and 27,871 tonnes). This discrepancy was valued at 43.6 million US$ for fin and 21 million US$ for meat products. Additional information about this discrepancy can be found in Supplementary **Figure S2.1**.

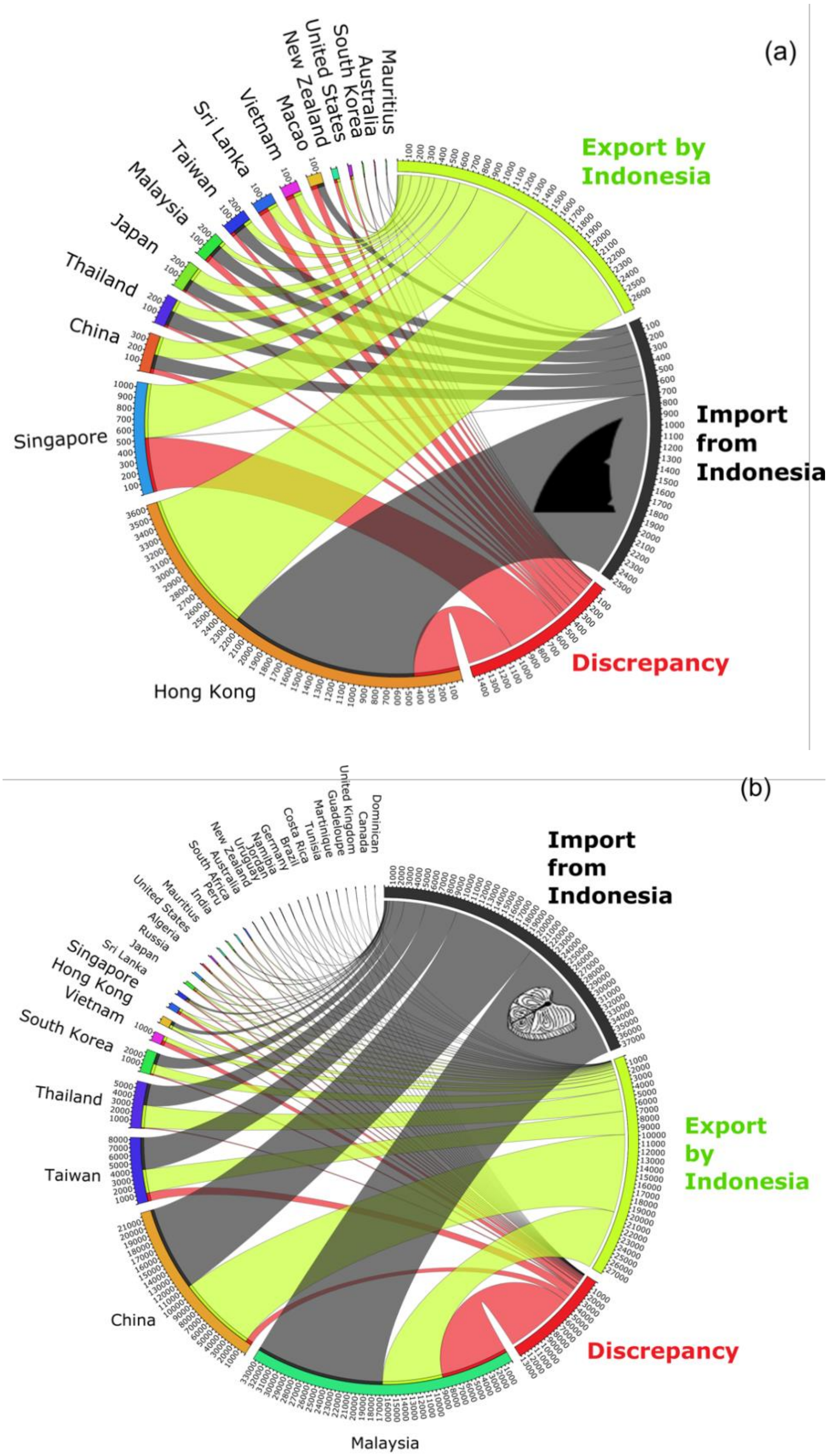

Figure 2.8. Trade flow and discrepancy of shark fin (a) and meat (b) products between Indonesia and its main trade partners, in tonnes, within the

2012-2018 period. Legend: Discrepancy (RED flow); the exported volume declared by Indonesia (GREEN flow), and the corresponding amount declared by each importing country (GREY flow). Source: (FAO, 2019)

2.4. Discussion

This study reveals inconsistencies in fisheries and trade statistics for the nation that lands the world's largest volume of elasmobranchs. These inadequacies are reflected in three main 'gaps', namely (i) the volume gap between landing and export, (ii) the information gap between the main landing site and main supplier at the domestic level, and (iii) the volume gap between export and reported import by trade partners. These issues sit at the core of the grand challenges facing shark population management globally.

As the top shark landing country, shark and ray landings are mainly caught as bycatch, particularly from commercial fishing gear such as tuna longline and gillnet/trammel-net (Booth et al., 2018). Since the reported export volume of sharks and rays is almost negligible (4%) compared to the total landing volume, difficulties remain with the partitioning of landings into domestic consumption and international components (Dent and Clarke, 2015), while the poor taxonomic granularity of catch (and trade) compositions represents a big obstacle to accurately monitor population trends for most species. This is especially important in highly populated, developing and biodiverse regions. Indeed, elasmobranch products sustain a diverse array of markets, from lucrative demands for traditional delicacies, supplies for medicines and cosmetics, curios, and substantial provision of food for local communities (Dent and Clarke, 2015, Thomas-Walters et al., 2020). The diversity and vulnerability of the living resources exploited, and the complex trade routes of their derivatives, calls for a step change in the ways data are recorded, fisheries are managed, and commercial activities regulated.

In several published studies, sharks and rays contributed between 5%-30% of the total catch (Novianto and Nugraha, 2014, Jatmiko et al., 2015, Pane et al., 2018, Suwarso et al., 2020). Despite the substantial volume of shark and ray landings in the most densely populated islands (Java and Sumatra) in Indonesia, we found that Papua and Bali Provinces (FMA 718 and FMA 573) were the main market sources of elasmobranch products (**Figure 2.6a**). Products from those main market sources were mainly transported to Jakarta and Surabaya where many exporters are located. Mismatch between landing and main supplier aside, unsystematic data recording possibly confounds the picture. Anecdotal information indicates that many elasmobranchs caught in the Arafura Sea (FMA 718) and many other eastern regions are shipped to Jakarta using cargo ships and landed in the cargo port, where they are recorded as a 'product' instead of catches by the Fishing Port Authority in Jakarta. It was also noticed that the Aceh Province in Sumatra Island shows no domestic trade record (**Figure 2.6b**), which suggests unreported exchanges among neighbouring provinces or even direct international trade with bordering countries, such as Malaysia and Singapore.

The investigation on the most recent six years of international trade statistics (2012 – 2018), reveals a cumulative export of 2,689 tonnes of fins and 27,871 tonnes of elasmobranch meat reported by Indonesia. Such products are mainly exported to Hong Kong, Malaysia, Singapore, China and Thailand. Hong Kong was the main market of fin products while Malaysia was the main destination of meat products (which mostly consisted of the fresh meat of rays). These bilateral trade depictions do not attempt to match elasmobranch commodities that were imported only to be subsequently exported (re-exports), as FAO data suggest that such re-exports are negligible.

Given the major difference between the export and import volume of elasmobranch products, the mismatch value was estimated using the average value between export and import in 2012-2018. Analysis of international trade shows significant discrepancy between export and import figures for fins and meat products by 1,462 tonnes and 13,138 tonnes respectively. This mismatch amounts to 54.4% of the total 2,689 tonnes export declared in the fin trade, which is valued at approximately 43.6 million US$ (based on the estimated value of 29,800 US$/ton). Gaps are mostly caused by the fin trade with Singapore (under-reporting) and Hong Kong (over-reporting), by 521 and 440 tonnes respectively. On the other hand, there was a mismatch of 47.1% of the reported export in the meat trade, a value of approximately 21 million US$ (based on the estimated value of 1,600 US$/ton), most of which is due to the underreporting of products putatively imported by Malaysia (nearly 9,000 tonnes). This highlights the economic loss due to the mismatch in meat products.

These gaps could be filled, at least to some extent, by increasing granularity of elasmobranch product types in the World Customs Organization (WCO) Harmonised System (HS) codes. Currently elasmobranch products can be traded into 12 HS categories, which mostly emphasize differences in processing, yet invariably aggregate all ‘sharks’, ‘dogfish’, and ‘rays’ in the same group (Supplementary **Figure S2.2**). This is of course insufficient to accommodate the high diversity of shark and ray species that regularly feature in traded products. It also reinforces concerns regarding the effectiveness of international measures to combat illegal trade (Cardeñosa et al., 2018, Alberts, 2020). Similar findings on trade discrepancy between Hong Kong and its partner countries highlighted the importance of comprehensive data recording on elasmobranch fin trade (Shea and To, 2017). It also advocates for the authorities to improve their capacity to reduce the risk that illegal products might contribute to such gaps. Disparities in trade statistics might exist for reasons other than illegal activity, such as measurement inaccuracy and shipment lags. Any attempt to deduce proof of illicit activity from statistical disparities must account for these other possibilities. Yet the sign of the discrepancy for sharks—reported exports tended to be lower than reported imports—implies that illegal trade activities were more likely to occur in Indonesia than in Indonesia's trading partners. Measurement error, shipment lags, and intentional underreporting all play a role in explaining discrepancies for both types of products. As an archipelagic country, Indonesia had difficulty comprehensively monitoring trade. For instance, there is no record of trade in shark products from Aceh Province. The use of land transpotation to the main hub, i.e., Medan, could explain this phenomenon. One of these illegal practices is direct trade with close neighboring countries. Intentional mislabeling may have occurred in order to avoid permits and was replaced with less regulated products, such as fish derivative products.

Anthropogenic impacts on functional diversity of marine megafauna, their ripple effect on ecosystem structure (Prasetyo et al., 2019, Sherman et al., 2020), and greater awareness of the value of marine predators when alive (Mustika et al., 2020) has led to increased global attention to elasmobranch conservation. However, without a comprehensive understanding on the market dynamics around elasmobranch resources, including domestic and international demand, conservation success is unlikely to be attained in the medium to long term (Bennett et al., 2017, Booth et al., 2019b, Glaus et al., 2019, Collins et al., 2020). The large discrepancy between the landing and export volumes needs to be examined in more detail in relation to the two main factors that could potentially explain these figures: the potential role of domestic consumption, and the potential for unreported/inaccurate trade figures.

CITES implementation should be periodically evaluated to examine its effectiveness and shifts in behaviour. It is also crucial to investigate any alteration of trade behaviour (i.e. route, volume and source) which may be counter-productive to CITES principles (Harfoot et al., 2018, Friedman et al., 2018, Booth et al., 2020). Without adjustments, coastal communities are unlikely to benefit from CITES implementation, which may instead render their business more uncertain; so a practical alternative is required for communities that depend on CITES species, optimising the benefits while minimizing the costs (Lavorgna et al., 2018). Other authors also have debated the effectiveness of the Convention's measures (Cochrane, 2015, Challender et al., 2015a, Challender et al., 2015b, Guggisberg, 2016, Booth et al., 2020), but the Indonesian context is unique in its complexity, whereby high species diversity, high harvested biomass, complex internal trade routes, local population needs, and poor reporting and the potential for illegal wildlife trade all combine to set major challenges for the sustainable management of sharks and rays. For instance, the implementation of CITES regulations rarely touches grass-roots stakeholders (i.e., fishers), who are the most impacted by the regulations, and tends to leave them with uncertainty and misinformation. This happened due to the misleading interpretation of the CITES regulations by a few authorities that assumed the framework applied to domestic utilization by communities, fishers and traders (Trouwborst et al., 2017). In fact, the CITES rules may only apply to trade within the country and fishing within its Exclusive Economic Zone (EEZ).

Mismatches between policy and management objectives could also detrimentally impact conservation efforts. For instance, MMAF issued decree no. 2/2015 concerning a trawl and seine-net ban in the Arafura Sea (FMA 718) in 2015 in order to address shrimp stock depletion (Wijopriono et al., 2019). The subsequent shift from trawling and seine-netting to trammel-net activity led to a significant increase of elasmobranch bycatch. Within two years (2016-2018), processing plants in Jakarta have rapidly expanded elasmobranch product supply. This is also mirrored in the international trade statistics, where the export of elasmobranch products (especially meat) increased dramatically since 2015. This is known as the "cobra effect" (Vann, 2003), whereby an attempted solution to a problem (i.e. overfishing of shrimp resources) actually makes the problem worse, and/or creates other unintended, problematic consequences (i.e. overfishing of endangered elasmobranchs). As secondary catches, elasmobranchs have added value for fisheries, while bycatch mitigation strategies remain inadequate to conserve these fragile creatures (MacNeil et al., 2020). Current management should be reconsidered to attain a better trade-off of conservation and management measures (Peterman, 2004).

In addition, increased international trade in live elasmobranchs is likely driven by the growing interest in displaying sharks and rays in public aquaria and theme parks (Morris et al., 2018). China, Hong Kong, Malaysia and USA are the main market for such commodities, which usually comprise coral reef associated species. This increased demand is anticipated to add complexity and additional challenges to monitoring and trade regulations. With the growing vulnerability of many elasmobranch species becoming apparent, there is an urgent need for the authorities to adopt trade regulations that incorporate policies to protect animal welfare in addition to conserving biodiversity (Booth et al., 2019a).

Successful shark and ray conservation measures require sufficient data collection (Dharmadi et al., 2015). Data collection in Indonesia is very challenging due to it being an archipelagic country and having a shortage of taxonomic expertise on elasmobranchs. For instance, there are issues with misidentification which is associated with catch records, such as in the cases of 'sawfishes' (Pristidae) and 'sawsharks' (Pristiophoridae), or 'wedgefishes' (Rhinidae) and 'guitarfishes' (Rhinobatidae). Some species of sharks have begun to be recorded separately to accommodate international trade measures, i.e. CITES. Requiem sharks (other Carcharhinidae) and thresher sharks (Alopidae) were the highest contributors to shark catches while rays were dominated by stingrays (Dasyatidae) and wedgefishes (Rhinidae). This is a major concern, as silky sharks (*Carcharhinus falciformis*), fall into the 'other Carcharhinidae' group, and wedgefishes, have both recently been added to international trade restrictions. Moreover, the two main fishing management areas (FMA) that contributed the largest elasmobranch catches (Java Sea and North Natuna Sea) are well-known as fishing grounds for wedgefishes and guitarfishes, and important bases for several fishing fleets that typically fish across other FMAs, such as FMA 713 (Makassar Strait) and FMA 718 (Arafura Sea).

Trade monitoring is further complicated by considering the volumes to be inspected, inspection locations and type of products. There are now 47 species of elasmobranchs listed in the CITES's Appendices as of 2019. The number of Appendix II listings then more than tripled at the 19th Conference of the Parties (CoP19) in 2022 where parties agreed to add another 104 elasmobranch species, including requiem sharks (Carcharhinidae spp.), hammerhead sharks, guitarfishes, and Brazilian freshwater stingrays. Many of these listed species are distributed in Indonesian and adjacent waters. Despite the valuable efforts by the B/LPSPL ('Balai/Loka Pengelolaan Sumber Daya Pesisir dan Laut'; Institute for Coastal and Marine Resource Management) authority of the Ministry for Marine Affairs and Fisheries to meet the three main principles of CITES (i.e. legality, sustainability, and traceability), limited resources still represent major challenges for authorities and exporters. Species identification is also extremely challenging since sharks and rays are processed in a myriad of ways, which makes the tracing of exports very difficult (Abdullah et al., 2020). Emerging DNA barcoding techniques that are affordable and reliable are pivotal for traceability (Cardeñosa et al., 2018). All these circumstances determine the intricacies of domestic and international trade flows in Indonesia (**Figure 2.9**), whose disentanglement will require multi-disciplinary approaches, solid collaboration and substantial engagement (**Figure 2.10**).

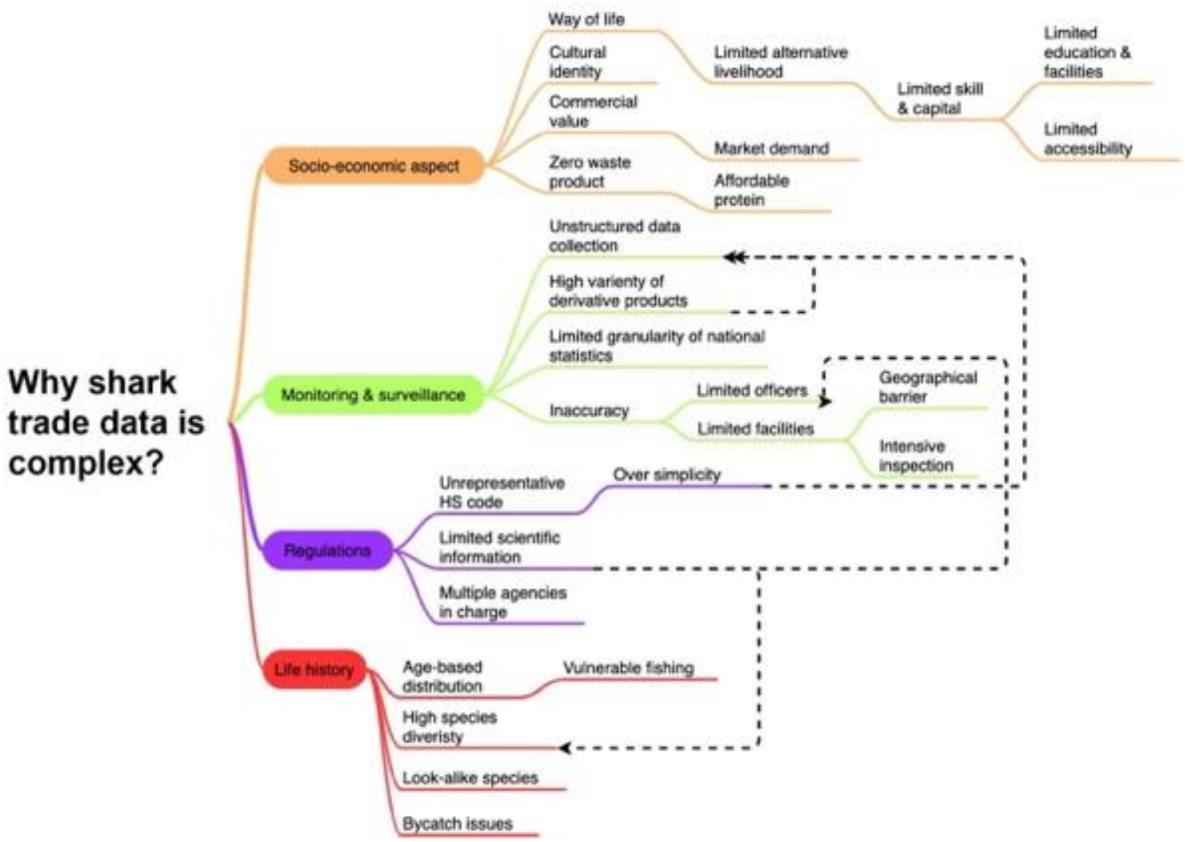

Figure 2.9. Causal diagram to explain the complexity of shark trade in Indonesia.

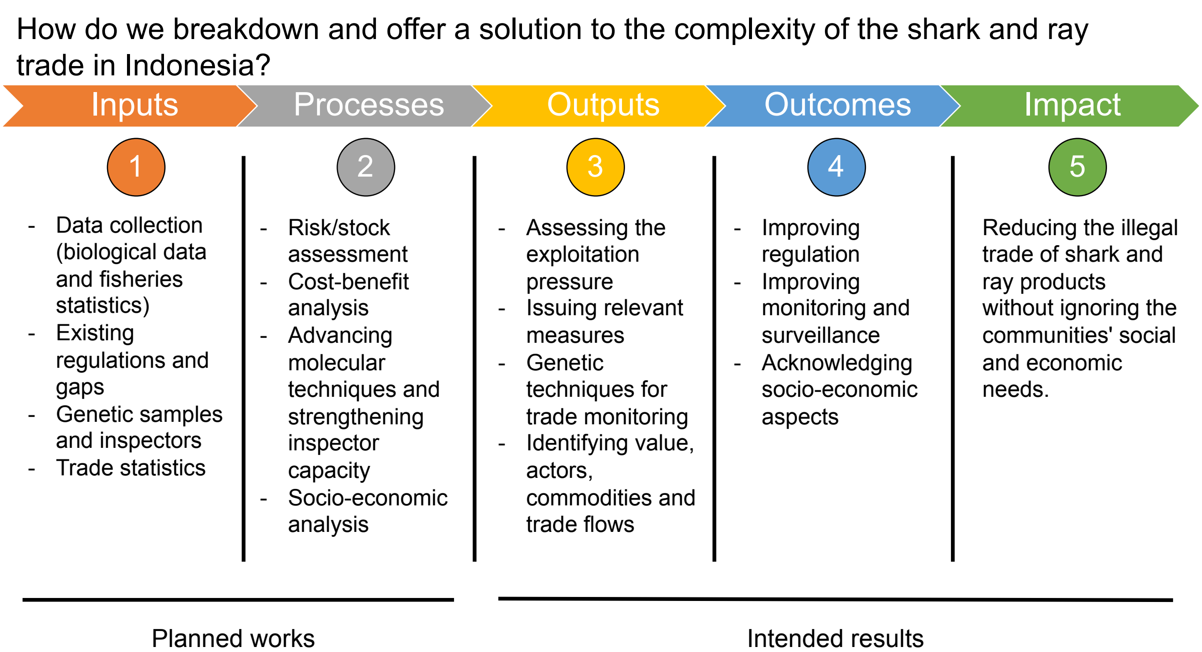

Figure 2.10. Theory of change framework to breakdown and offer a solution to the complexity of the shark and ray trade in Indonesia.

2.5. Conclusion

We have made a major step towards understanding historical and current trends in landing, domestic flow and international trade of sharks and rays in Indonesia. We found that species catch recording, domestic traceability, and international trade are all inadequate to guarantee the long-term conservation of these living resources. There is also great doubt that the value chain is fair to fishers and local operators, especially concerning valuable products that are exported (the main export commodities of shark parts were fin, cartilage and other derivatives, while other less valuable products, such as meat, are mainly for domestic consumption (Muttaqin et al., 2018, Dharmadi et al., 2019)). An increase of elasmobranch species listed in the CITES Appendices highlights the importance of improving national capabilities to monitor the supply chain, from capture to consumers/importers. The current scenario calls for efforts to be made towards: i) increasing taxonomic resolution of landing and trade statistics, ii) standardisation of product-based HS codes to facilitate consistent naming among authorities (Cawthorn et al., 2018); iii) expanding national capabilities in technologies (e.g. DNA testing, (Cardeñosa et al., 2018)) designed for accurate product identification; iv) taking into account the socio-economic aspects of the fisheries to feed into more effective conservation and management measures.

Community participation is a vital requirement to consider in the early stages of a management plan, and it will also be helpful for the surveillance and stewardship of the management action implemented in the often unique socio-ecological system in question (Syakur et al., 2012). A typical example is the often touted ‘shark tourism solution’, which only works in certain places and for certain species (Booth et al., 2020), and is bound to fail without effective community engagement (Mustika et al., 2020). As a whole, we recommend better integration of fisheries and trade management, improved data collection, and increased community engagement to create the required incentives and frameworks for conservation and sustainability, which may work for both elasmobranchs and people.

Data and materials availability

Data and scripts related this chapter are available at https://github.com/andhikaprima/Prasetyo_et_al_Indonesia_Sharks_Trade.

Additional information

Supplementary information

Figure S2.1. Domestic trade network of fin and meat products across Indonesia region within 2014-2018 (ton)

Figure S2.2. Annual volume of reported export and import by/from Indonesia in 2012-2018 for fin products (a) and meat products (b)

Table S2.1. Shark and ray production and trade data used in this study. Trade data include HS Code and descriptions of shark and ray commodities.

Table S2.2. Shark product HS codes used in trade, 2008–2018 (UN Comtrade)

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Chapter 3

Can universal closed-tube barcoding technology improve trade monitoring of shark and ray products in Indonesia?

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Prasetyo, A. P., M. Cusa, J. M. Murray, F. Agung, E. Muttaqin, S. Mariani and A. D. McDevitt (in review). Universal closed-tube barcoding for monitoring the shark and ray trade in megadiverse conservation hotspots.

Figure 3.1. Demonstrating FASTFISH-ID technology in one of the processing plants for shark and ray derivatives products in Indramayu.

Abstract

Trade restrictions for many endangered elasmobranch species exist to disincentivise their exploitation and curb their declines. However, the variety of products and the complexity of import/export routes make trade monitoring challenging. We investigate the use of a portable, universal, DNA-based tool which would greatly facilitate in-situ monitoring. We collected shark and ray samples across the Island of Java, Indonesia, and selected 28 species (including 22 CITES-listed species) commonly encountered in landing sites and export hubs to test a recently developed real-time PCR single-assay originally developed for screening bony fish. We employed a deep learning algorithm to recognize species based on DNA melt-curve signatures. By combining visual and machine learning assignment methods, we distinguished 25 out of 28 species, 20 of which were CITES-listed. With further refinement, this method can provide a practical tool for monitoring elasmobranch trade worldwide, without the need for a lab or the bespoke design of species-specific assays.

Keywords: elasmobranchs, universal closed-tube barcoding, machine learning, trade monitoring, Indonesia

3.1. Introduction

Biodiversity is depleting more rapidly than at any time in human history. Within the last 50 years, animal species have declined by an average of almost 70% due to continued and increasing anthropogenic stressors (Bar-On et al., 2018, Leung et al., 2020), including the dramatic reduction of shark and ray populations (hereafter referred to as 'elasmobranchs' (Dulvy et al., 2014, MacNeil et al., 2020). Fishing pressure (whether targeted or by-catch) is the major threat to elasmobranchs, leading to one of the highest extinction risks across the animal kingdom (Pacoureau et al., 2021). Although some elasmobranch fisheries can be sustainably managed (Simpfendorfer and Dulvy, 2017), the market demand for shark and ray products typically leads to overexploitation of elasmobranch resources (Clarke et al., 2006, Dulvy et al., 2014).

The rapid global decline of elasmobranch populations requires collaborative management and conservation to ensure the long-term benefits of these populations to the wider ecosystem and for human resource use. Binding international trade conventions such as CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) regulate and provide the framework to restrict the international trade of priority species by creating species listings (CITES appendices I, II and III). Indeed, there has been an increasing number of elasmobranch listings in CITES Appendix I and II over the last decade with 38 of the 47 species regulated by CITES added at the 16th (2013), 17th (2016) and 18th (2019) Conference of the Parties conventions (Booth et al., 2020). The number of Appendix II listings then more than tripled at the 19th Conference of the Parties (CoP19) in 2022 where parties agreed to add all remaining (54) species of requiem sharks (Carcharhinidae spp.), 6 species of hammerhead sharks, and 37 species of guitarfishes to Appendix II. Seven species of Brazilian freshwater stingrays were also adopted for Appendix II listing. The scale and pace of these listings (now 151 species) present an important implementation challenge for countries with large and diverse landings of sharks and rays, such as Indonesia.

As a result of substantial bycatch, Indonesian fisheries hold the world's largest volume of elasmobranch landings (FAO, 2022, Fahmi and Dharmadi, 2015). This exploitation contributes to the high vulnerability rate of elasmobranch populations in Indonesian waters (Mardhiah et al., 2019), including the populations in its coral reef ecosystems (MacNeil et al., 2020). This is particularly concerning as Indonesia harbours almost a quarter of the world's elasmobranch diversity (Ali et al., 2014, Ali et al., 2018). Despite this, export volumes of elasmobranch products from Indonesia represent only a small fraction of its landing volume (FAO, 2021), which likely reflects its communities' high dependency on shark and ray as an alternative protein source (Muttaqin et al., 2018, Dharmadi et al., 2019b, Prasetyo et al., 2021). Several measures have been established by the Indonesian authorities to reduce the decline of elasmobranch populations, such as: increasing the number of protected species, extensive outreach programmes, improvement of data collection and stock assessment, expansion of marine protected areas, as well as the establishment of port state measures to combat illegal fishing (Dharmadi et al., 2015, Booth et al., 2018, Oktaviyani et al., 2019, Nugraha et al., 2020).

The issue around elasmobranch fisheries is rendered even more challenging by the myriad of shark and ray product derivations, which add another layer of complexity (Dent and Clarke, 2015, Shea and To, 2017, Safari and Hassan, 2020). Due to their similarity in appearance and the lack of distinctive features in most derivative products, elasmobranch species can be deliberately or accidentally mislabelled by those involved in the trade (**Figure 3.2**). The general lack of transparency in the trade of living resources is an ongoing concern for fisheries and conservation management (Naaum and Hanner, 2016) and can have a negative impact on stock management, and damages the reputation of entire sectors and countries (Naaum and Hanner, 2016, Cawthorn and Mariani, 2017). Furthermore, the continuous increase of elasmobranch species listed in the CITES Appendices requires constant improvements of national and transnational capabilities in monitoring the supply chain (Pavitt et al., 2021).

Figure 3.2. Condition of inspection and some derivatives products from shark and ray i.e. large volume of mix cartilages waiting for inspection (a); two containers full of dried shark and ray skin (b); inspectors checking a mixed bag of small fin and finding some hammerhead species' fins (c); caudal fins being dried (d); shark teeth (e); processed ray skin (f); shredded fins 'hissit' in brine ready for exporting to Japan (g); blue shark cartilages soaked for processing (h); dried meat from small sharks (i); dried meat from a large shark (j); live bowmouth guitarfish for the aquarium market (h); and dried fin of silky and hammerhead sharks waiting for quota to export (l).

The rapid development of DNA-based diagnostic tools offers an ever-expanding option for wildlife identification, which have greatly assisted elasmobranch biology and forensics. Established DNA barcoding (Shivji et al., 2002) and mini-barcoding (Fields et al., 2015) approaches can robustly identify species in fresh and processed samples. However, these traditional DNA barcoding methods require longer processing time and high costs for their sequencing processes. More recently, advances in real-time PCR have eliminated the sequencing stage, thereby allowing species identification to be conducted in the field. This approach uses target-specific primers and fluorescent dyes to detect the presence of the targeted nucleic acid template during PCR amplification and has been successfully applied to detect several CITES-listed shark species in a single run tube (Cardeñosa et al., 2018) and Multiplex LAMP (Lin et al., 2021). However, given their reliance on species-specific primers and probes, these methods are better suited to screening large numbers of specimens from one or few species rather than from a wide variety of species. Thus, the need remains for a fast and easy way to identify any sample, by-passing the need to design species-specific assays.

This issue is particularly glaring when inspectors are dealing with multiple types of products from different species across many locations and with a limited timeframe to investigate species compositions (Prasetyo et al., 2021). This year, the magnitude of the challenge has more than tripled, with the number of CITES-listed species going from 47 to 151 (Collyns, 2022, CITES, 2022). Since CITES regulations still allows species listed on Appendix II to be traded by considering the sustainability of exploitation through a Non-detrimental Findings (NDF) framework, trade monitoring is more crucial than ever before.

In an attempt to circumvent the limits of species-specific methods, a universal single-tube assay marketed as FASTFISH-ID™ was recently developed for use in the seafood industry (Naaum et al., 2021). This method uses LATE (Linear-After-The-Exponent) PCR to amplify one strand of the full 650bp COI barcoding region (Sanchez et al, 2004), and uses a set of fluorescent probes to target two distinct mini-barcode regions selected for their high inter-specific variability which will then produce unique species-specific fluorescent signatures (Naaum et al., 2021). The fluorescent signatures are then compared to those kept in a cloud-based library of verified specimen signatures.

However, this approach and its libraries were originally designed and validated for bony fishes (Naaum et al., 2021) and no elasmobranch fluorescence fingerprints are publicly available in the FASTFISH-ID^{TM} cloud. We therefore chose to test i) whether the existing FASTFISH-ID^{TM} diagnostics could produce a diverse range of fluorescent signatures unique and specific to each of the 28 elasmobranch species frequently found in Indonesian trade; and ii) whether a deep machine learning method could quantitatively assign signatures to the correct species, irrespective of the visual appearance of the fluorescence. Deep learning algorithms are highly flexible and well suited for undertaking these tasks (LeCun et al., 2015, Malde et al., 2019), and have recently been applied in marine science, including fish size estimation (Garcia et al., 2019), bycatch detection and shark identification from photos and videos (Sharma et al., 2018, Peña et al., 2021, Jenrette et al., 2022). Our findings indicate that this portable, universal methodology performs well even for ‘non-target’ elasmobranch species, and with further refinement, it can become a powerful tool to combat the illegal trade of endangered sharks and rays.

3.2. Materials and methods

3.2.1. Sample collection and DNA extraction

Indonesia’s geographical location and its vast and complex coasts make it a unique and emblematic marine megadiversity hotspot. Between 2007 and 2017, Indonesia was the world’s top elasmobranch landing country (Okes and Sant, 2019), but export statistics revealed substantial knowledge gaps and inaccuracies (Prasetyo et al., 2021). Here we targeted several sites nested in six locations across cities on Java Island, the most populous island in Indonesia (**Figure 3.3**) and the main export hub for various commodities, including elasmobranch products. The locations included fishing ports (FP), traditional markets (TM), elasmobranch processing plants (PP), export hubs (EH) and an inspector station (AU).

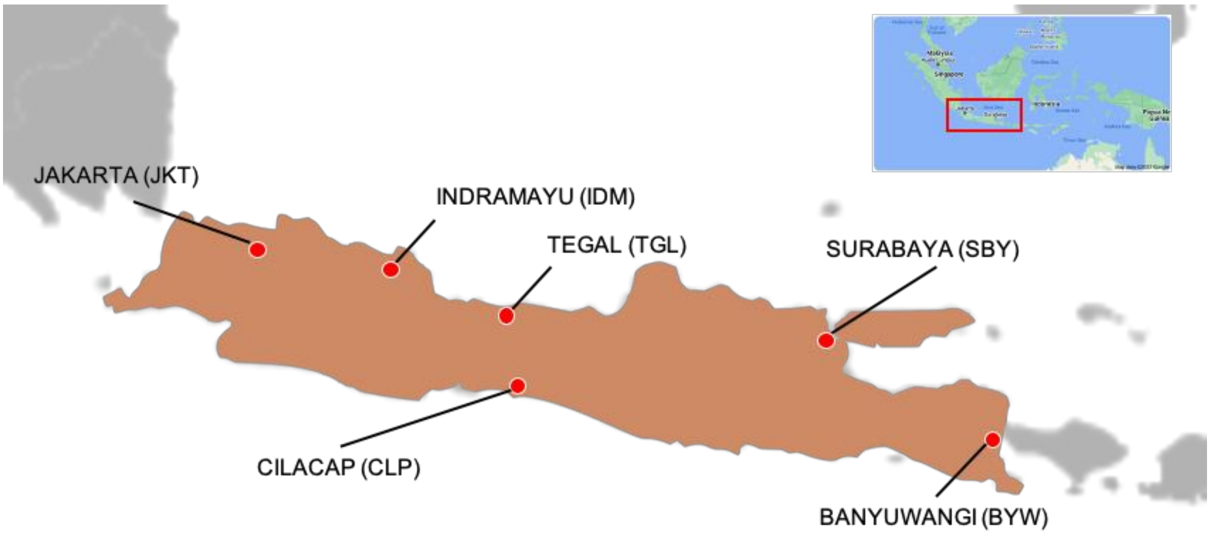


Figure 3.3. Sampling locations across Java Island, Indonesia. Locations are labelled with long and short codes.

579 specimens were opportunistically collected at the above-mentioned sites and processing factories throughout January and February 2020. The tissue, which could either be fresh, frozen, partially or heavily processed, was then stored in 2.0mL screw-cap microcentrifuge tubes, submerged in 90% ethanol and stored at 4°C. DNA was extracted from samples following the Mu-DNA protocol for tissue samples (Sellers et al., 2018) with an overnight incubation at 55°C on the thermomixer with a medium mixing frequency and a final elution volume of 100 µl. All surfaces were sterilised with 50% bleach and then washed with 70% ethanol, in-between and after extracting each sample, to reduce cross-contamination risks (**Figure S3.1a-b)**.

Of these, we excluded specimens of unclear taxonomy, and all species represented by less than 3 individuals. We refined the collection to 130 tissue samples (specimens) belonging to 28 species; for each species, we used three replicates per specimen as training sets (390 runs) (**Table S3.1)**. We also had another 68 tissue samples without replication and used them as testing datasets (**Table S3.2)**. As sampling was conducted opportunistically, we did not have an equal number of samples per species. Some species had a limited number of specimens, so we took out some training sets to be used as testing datasets. Datasets were then filtered, and ambiguous real-time PCR runs (i.e. poor probe-barcode hybridisation or inconsistent fluorescent signature) were removed. A poor probe-barcode hybridisation was checked using a reference point created by ThermaMark^{TM} (TM) in the signature produced from BS1. If only ThermaMark^{TM} (TM) amplified in the BS1 fluorescent signature, those runs would have failed to hybridize. Inconsistent fluorescent signatures within a replication or species were re-run a second time. If the re-runs kept failing, those runs were removed. In the end, we used 357 (number of replications varied by specimens) and 68 runs for training and testing datasets, respectively.

3.2.2. FASTFISH-ID^{TM} closed-tube barcoding protocol

PCR reaction and amplification conditions

In the first instance, the FASTFISH-ID^{TM} method requires the amplification of the full cytochrome c oxidase I (COI) gene (~650 bp) and in the second instance, it targets the two mini-barcodes (~80 bp) using a set of probes. PCR master mixes were prepared in low-adhesion Eppendorf tubes (Naaum et al., 2021). The major components of this method are ThermaStop^{TM}, ThermaMark^{TM} and FASTFISH-ID^{TM} Probe Mix (Ecologenix, LLC.). ThermaStop^{TM} is a novel hot-start reagent that prevents non-specific amplification prior to the start of the reaction, while ThermaMark^{TM} (hereafter referred as TM) is a temperature-dependent marker for correction of melt-curve analysis (Ecologenix, LLC.). The FASTFISH-ID^{TM} probe mix consisted of two sets of positive/negative probe pairs labelled in two different colours that hybridize along the length of two mini-barcode regions within the amplified COI target sequence, hereafter referred to as Barcoding Segment 1 (BS1) and Barcoding Segment 2 (BS2). A M13 primer was used as a priming site that facilitates the sequencing process for eventual species validation through Sanger sequencing.

FASTFISH-ID^{TM} uses asymmetric PCR to produce more single stranded amplicons which allow the probes to hybridize more easily (Sanchez et al., 2004). After amplification, mismatch tolerant positive/negative probe pairs bind to their single-stranded DNA targets. Each positive-probe is formed of a target binding sequence that is 20–35 nucleotides long and has a higher fluorescent signal when it is bound to its target sequence but a low background fluorescence when it is not. Negative-probes are only quenchers that reduce the fluorescent signal when they are bound next to their paired positive-probe. Positive/negative probe pairs can bind to both perfectly matching strands and target sequence variants with one or more nucleotide polymorphisms. This means that they can tolerate mismatches, which is one of the most important features of this technology as a single set of reagents can be used to identify a large number of species (Naaum et al., 2021). Target sequences that are similar but different, even if only by one nucleotide, almost always have different fluorescent signatures. Positive/negative probe sets therefore have the potential to discriminate among thousands of fish species and their variants (Naaum et al., 2021).

PCR amplification was performed on a Magnetic Induction Cycler (MIC) which is a real-time PCR thermocycler designed by Bio Molecular Systems™ (Upper Coomera, Queensland, Australia). Thermocycling conditions were 94°C for 2 mins, 5 cycles of 94°C for 5 secs, 55°C for 20 secs, 72°C for 45 secs, then 65 cycles of 94°C for 5 secs, 70°C for 45 secs (in total: 2 hrs, 20 mins and 44 secs). Following a total of 70 amplification cycles, the reaction leads to a 10- to 20-fold excess of single-stranded DNA which is critical for probe/target hybridization in a single closed tube (Sanchez et al., 2004, Pierce et al., 2005). At the completion of PCR, the temperature was decreased down to 40°C for 10 mins to enable the fluorescent probes in the FASTFISH-ID™ probe mix to hybridize to the excess single-stranded DNA. This step was followed by a melting curve analysis where the temperature was gradually increased from 40°C to 87°C at 0.1°C /secs with sequential fluorescent acquisition first in the MIC PCR Cycler's Orange Channel (suitable for detection of CalRed 610-labelled probes; max excitation: 590 nm; max emission 610 nm) and then detection in the Red Channel (suitable for detection of Quasar 670-labelled probes; max excitation: 647 nm; max emission 670 nm). The first derivative of the melt curve was then used as the fluorescent signature. Species assignment was revealed by comparing a distinct mix of Cal-Red 610 and Quasar 670 fluorescent signatures (**Figure S3.1c-f**). Those multiple combinations allow FASTFISH-ID™ to identify a large number of species with the same reagents (Rice et al., 2012, Sirianni et al., 2016, Naaum et al., 2021).

DNA barcoding and species validation

The same single strand DNA products used to generate a fluorescent signature can also be sequenced by DNA barcoding for further investigation. The sequencing protocol uses the M13 tail sequence in the FASTFISH-ID™ FISH COI HBCts excess primer (5' CACGACGTTGTAAAACGAC 3', a modified version of the M13F primer) as a sequencing primer to generate the sequence of the excess primer strand. By design, the excess primer-strand sequence can be queried directly in the NCBI nucleotide database (NCBI, 1988) or the Barcode of Life Database (Ratnasingham and Hebert, 2007) for species identification. In addition, we also used Fish F2 (5’ TCGACTAATCATAAAGATATCGGCAC 3’) and Fish R2 (5′ ACTTCAGGGTGACCGAAGAATCAGAA 3′) primer sets (Ward et al., 2005) for several initial specimens for comparison with HBCts excess primer (M13). Sequencing was outsourced to Macrogen Europe™. Samples were prepared according to the service provider protocols (https://www.macrogen-europe.com/services/sanger-sequencing). We also added species and/or specimens after identification using a highly degenerated primer set using a high throughput barcoding (HTB) method (A.P. Prasetyo et al., *unpublished data*); Leray-XT primer sets (313 bp). This set included the primers jgHCO2198 (5′ TAIACYTCIGGRTGICCRAARAAYCA 3′) and mlCOIintF-XT (5′ GGWACWRGWTGRACWITITAYCCYCC 3′) (Wangensteen et al., 2018).

3.2.3. Machine learning for species assignment

Since the two probing barcode segments and the algorithm were developed for teleost fishes, they are not expected to maximise differentiation among the melt curves of elasmobranch species. Furthermore, the existing cloud-based reference library does not contain any elasmobranch signatures. We therefore developed our own species identification system by using machine learning using the H2O platform (**Figure S3.1h-g)**. H2O is an open source, fast and scalable machine learning and predictive analytics platform that allows building machine learning models on big data, and improving reproducibility (Candel et al., 2016). The deep learning algorithm was deployed to address the problem of species assignment by considering its capability to arrange multiple nonlinear transformations to model high-level abstractions in data. H2O’s Deep Learning is based on a multi-layer feedforward artificial neural network (FANN) that is trained with a stochastic gradient descent using a backpropagation environment (Candel et al., 2016). Deep learning is also advantaged by extracting the optimal input representation from raw data without user intervention (Avci et al., 2021).

The fluorescent signature datasets (BS1 and BS2) were extracted, with the species identity serving as the "response", and the transposed PCR profile temperature values being used as the predictor "variables" (each barcode fragment is recorded at about 4,000 temperature values), and fluorescent values serving as the "feature". In deep learning, "response" refers to the individual value that served as the output (species name in our case); while "variable" refers to properties of the "response" and is evaluated through the "feature".

The performance of deep learning algorithms depends heavily on the extracted features, so it's important to choose the right group of features that best represent the input data (Pouyanfar et al., 2018). Data filtering was conducted to exclude poor probe-barcode hybridisation or inconsistent fluorescent signature datasets and provided the best representative of the data input. Two datasets (BS1 and BS2) were then merged by specimen ID with species name used as an input to the model. Our model was divided using a 70–30 ratio of training data to validation data (i.e. 246 and 111 runs respectively) and then tested with 68 independent datasets. Default parameters of H2O's Deep Learning were optimized, with a process called "grid-search", this process tried to adjust several parameters to find the optimal "stopping criteria" (list of parameters provided on **Table S3.3**). We setup a "stopping criteria" to limit the computational load in searching for the best deep learning algorithm, which was based on random discreteness, the number of generated models, and model runtime (**Table S3.4**). The best model was chosen based on model accuracy and Root Mean Square Error (RMSE) optimization. A confusion matrix is used to visualize model accuracy.

As for other algorithms, larger databases are required to improve predictive abilities by optimizing distributed representation, activation function non-linearity, and flexible architecture depth in terms of hidden layers and nodes (Calzolari and Liu, 2021). The main challenges in applying deep learning is overfitting due to a dominant influence on the generalization ability of a deep neural network model (Li et al., 2019). However, regularization methods such as Ivakhnenko's unit pruning (Ivakhnenko, 1971) or sparsity (l_1-regularization) or weight decay (l_2-regularization) can be applied during training to combat overfitting (Bengio et al., 2013). The sparsity and weight decay were used in this study.

3.3. Results

3.3.1. Fluorescent signature of species

After filtering and removing 33 inconsistent runs, 357 pairs of fluorescent signatures from 28 species were generated, including 14 sharks and 14 rays, with 22 of those species (12 sharks, 10 rays) being CITES-listed species. Within 2.5 hours, all types of samples - from fresh to processed samples sourced from different body parts - were amplified and produced one or two fluorescent signatures (referred to as BS1 and BS2 for barcode segment one and barcode segment two) (**Table S3.1** and **Table S3.2)** These two barcode segments refer to the two mini-barcode regions within the amplified COI target sequence that emitted fluorescent to be read by the real-time PCR machine.

Many species were distinguishable using a combination of both barcode segments and had unique signatures, such as *Alopias pelagicus* (pelagic thresher), *A. superciliosus* (bigeye thresher) and *Isurus paucus* (longfin mako shark). However, some species displayed probe-barcode hybridisation difficulties (see Methods), with more shark species (7) than ray species (3) being affected, namely *Carcharhinus falciformis* (silky shark), *C. longimanus* (oceanic whitetip shark), *I. oxyrinchus* (shortfin mako shark), *Lamna nasus* (porbeagle shark), *C. brevipinna* (spinner shark), *Galeocerdo cuvier* (tiger shark), *Prionace glauca* (blue shark), *Rhynchobatus laevis* (smoothnose wedgefish), *Glaucostegus typus* (giant shovelnose ray), and *Pristis pristis* (Largetooth sawfish). Nevertheless, some of the species displaying poor probe-barcode hybridisation remained distinguishable using the alternative barcode segment (**Table 3.1** and **Table S3.2-5**).

Table 3.1. Amplification conditions of each species using the targeted segments using the FASTFISH-ID technology. Probe hybridization condition denotes whether the species hybridized amplified at either or both segments (BS1 and BS2) and whether the species was distinguishable from all other species by its fluorescent signature(s) and deep learning.

No.	CITES status	Scientific name	English name	Probe hybridization Condition		Distinguishable	
				Barcode segment 1 (BS1)	Barcode segment 2 (BS2)	Visual	Deep Learning
1	Yes	*Alopias pelagicus*	Pelagic thresher	Yes	Yes	Yes	Yes
2		*Alopias superciliosus*	Bigeye thresher	Yes	Yes	Yes	Yes
3		*Carcharhinus falciformis*	Silky shark	Yes	No	No	Yes
4		*Carcharhinus longimanus*	Oceanic whitetip shark	No	Yes	Yes	No
5		*Isurus oxyrinchus*	Shortfin mako shark	No	Yes	Yes	Yes*
6		*Isurus paucus*	Longfin mako shark	Yes	Yes	Yes	Yes*
7		*Lamna nasus*	Porbeagle shark	No	Yes	Yes	Yes
8		*Sphyrna lewini*	Scalloped hammerhead	Yes	Yes	Yes	Yes
9		*Sphyrna mokarran*	Great hammerhead	Yes	Yes	Yes	Yes
10		*Carcharhinus brevipinna*	Spinner shark	Yes	No	Yes	Yes
11		*Carcharhinus sorrah*	Spot-tail shark	Yes	Yes	Yes	No
12		*Prionace glauca*	Blue shark	Yes	No	No	Yes*
13		*Anoxypristis cuspidata*	Knifetooth sawfish	Yes	Yes	Yes	Yes
14		*Glaucostegus typus*	Giant shovelnose ray	No	No	No	No
15		*Mobula birostris*	Giant oceanic manta ray	Yes	Yes	No	Yes
16		*Mobula mobular*	Giant devil ray	Yes	Yes	No	Yes
17		*Mobula tarapacana*	Sicklefin devil ray	Yes	Yes	Yes	Yes
18		*Pristis pristis*	Largetooth sawfish	No	Yes	Yes	Yes
19		*Rhina ancylostoma*	Bowmouth guitarfish	Yes	Yes	Yes	Yes

No.	CITES status	Scientific name	English name	Amplification Condition		Distinguishable	
				Barcode segment 1 (BS1)	Barcode segment 2 (BS2)	Visual	Deep Learning
20		*Rhynchobatus australiae*	Whitespotted guitarfish	Yes	Yes	Yes	Yes
21		*Rhynchobatus laevis*	Smoothnose wedgefish	No	Yes	Yes	Yes*
22		*Rhynchobatus springeri*	Broadnose wedgefish	Yes	Yes	Yes	Yes*
23	No	*Galeocerdo cuvier*	Tiger shark	No	No	No	No
24		*Stegostoma fasciatum*	Zebra shark	Yes	Yes	Yes	No
25		*Gymnura poecilura*	Longtail butterfly ray	Yes	Yes	Yes	Yes
26		*Himantura imbricata*	Bengal whipray	Yes	Yes	Yes	Yes
27		*Neotrygon orientalis*	Oriental bluespotted maskray	Yes	Yes	Yes	Yes
28		*Telatrygon zugei*	Pale-edged stingray	Yes	Yes	Yes	Yes
Total distinguishable species						**22**	**23**

Note: species with Asterix "" mark have probability of mis-assignment by the deep learning model*

Based on visual evaluations, the generated melt curves showed different fluorescent signatures for closely related species, such as thresher sharks (*Alopias* spp.) and hammerheads (*Sphyrna* spp.; **Figure 3.4**). Across the two species of thresher sharks, FASTFISH-ID^{TM} produced visually distinguishable curves in BS1 at the initial stages of the hybridization process and produced a similar drop at ~74-79°C, while the signatures in BS2 were clearly distinct in the initial stages (about 42-47°C). Some species, on the other hand, have virtually identical BS1 signatures but are distinguishable using BS2, such as in the case of zebra shark (*Stegostoma fasciatum*) and spot-tail shark (*C. sorrah*) (**Figure 3.5**). However, there are problematic species pairs that have highly similar signatures with both segments and therefore appear visually indistinguishable. This is the case between the tiger shark and giant shovelnose ray, between the silky and blue sharks, and between the giant oceanic manta and giant devil ray (two *Mobula* species), which have nearly identical signatures in both barcode segments (**Figure 3.6**). Overall, six out of 28 species were deemed visually indistinguishable, four of which are CITES-listed. We also found seven species that amplified inconsistently; shortfin mako shark (*Isurus oxyrinchus*), oceanic whitetip shark (*C. longimanus*), porbeagle shark (*Lamna nasus*), tiger shark (*Galeocerdo cuvier*), largetooth sawfish (*Pristis pristis*), giant shovelnose ray (*Glaucostegus typus*) and smoothnose wedgefish (*Rhynchobatus laevis*). It was observed that the right-most trough in the BS1 fluorescent signature labelled "TM" corresponds to ThermaMark, an internal marker for correction of artefactual temperature variation (**Figure S3.6**). However, in BS2, some segments were amplified and unique for each of these species.

Half of the samples were highly processed products, but they still amplified well. In some of these, there were differences in the intensity of the signatures, as reflected in signature variation from BS2 of great hammerhead, zebra shark and bowmouth guitarfish (**Figure 3.4, Figure 3.5** and **Figure S3.5**), which may in part be ascribed to the actual state of degradation of the original DNA template.

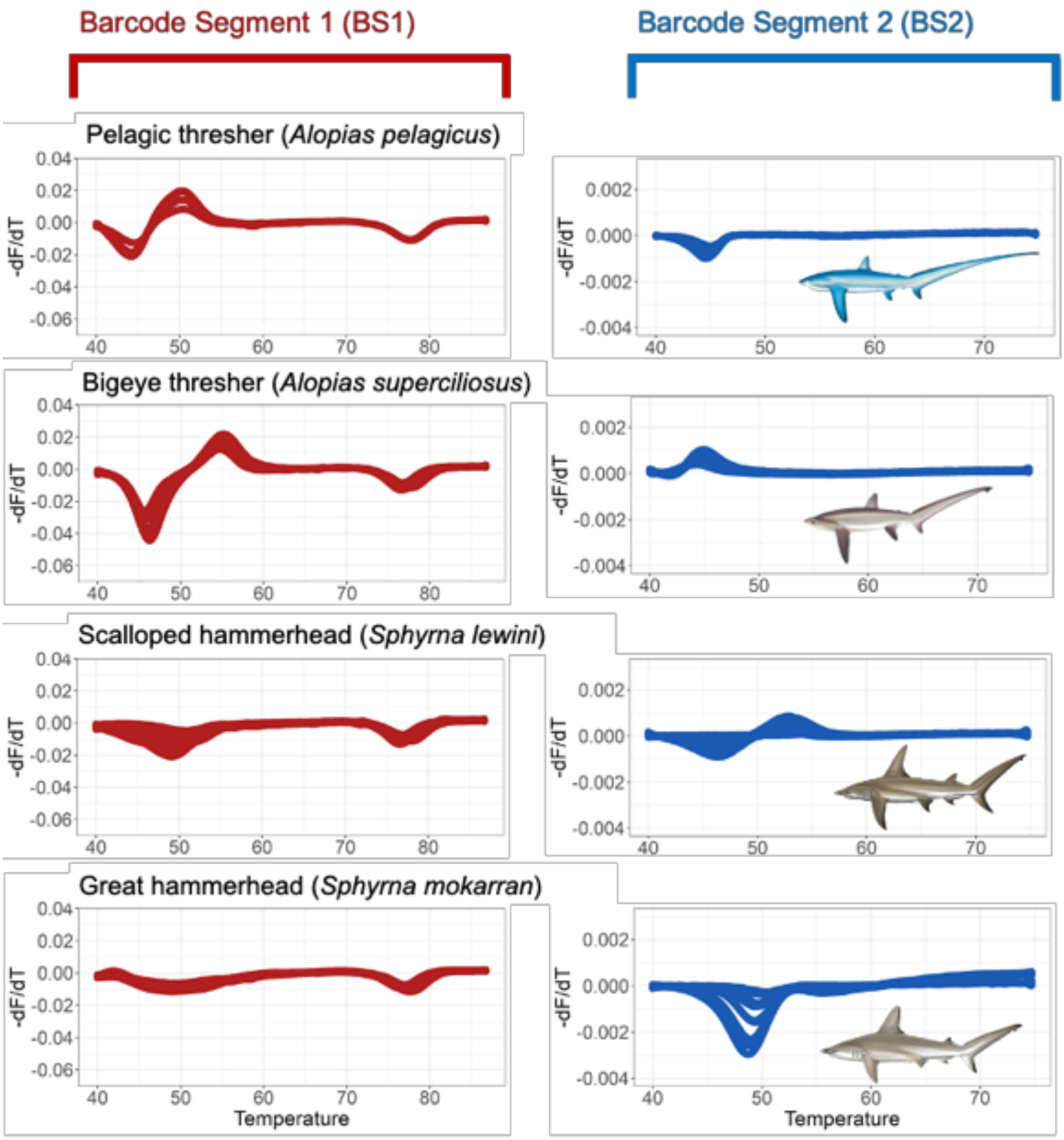


Figure 3.4. Some species that have visually distinguishable signatures in both barcode segments i.e. pelagic thresher, bigeye thresher, scalloped hammerhead and great hammerhead.

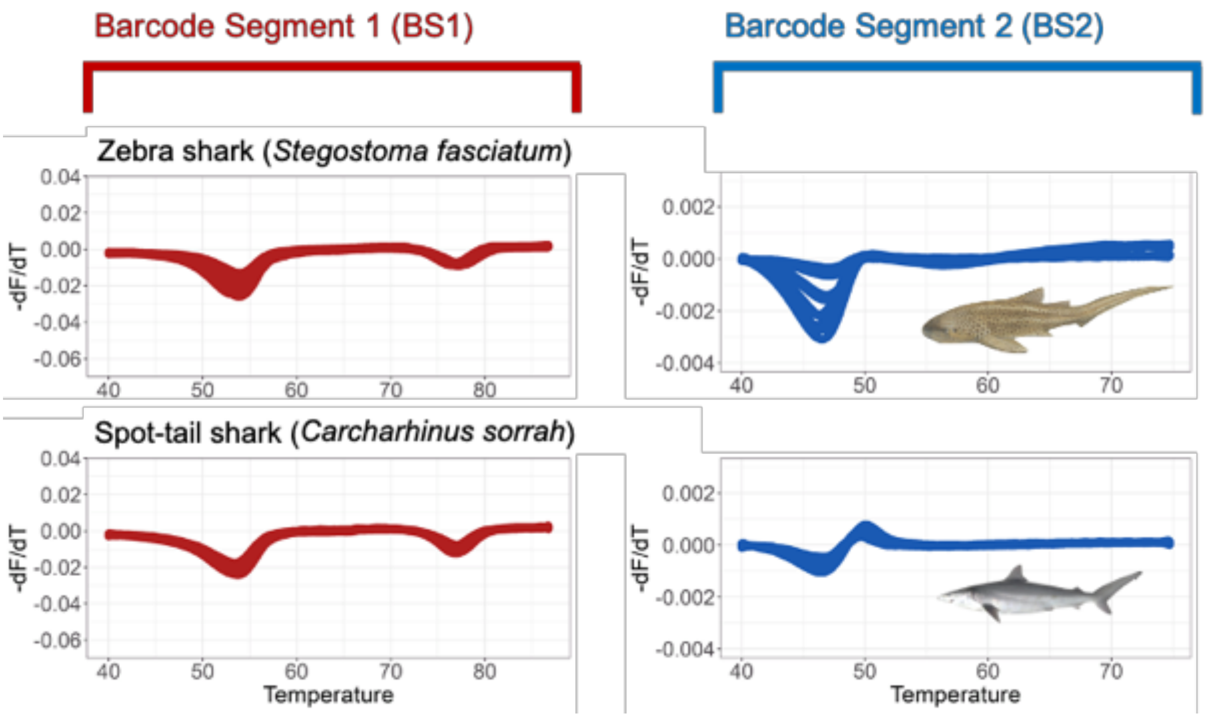


Figure 3.5. Some species that have similar signature in one barcode segment but visually unique in other segment i.e. zebra and spot-tail shark.

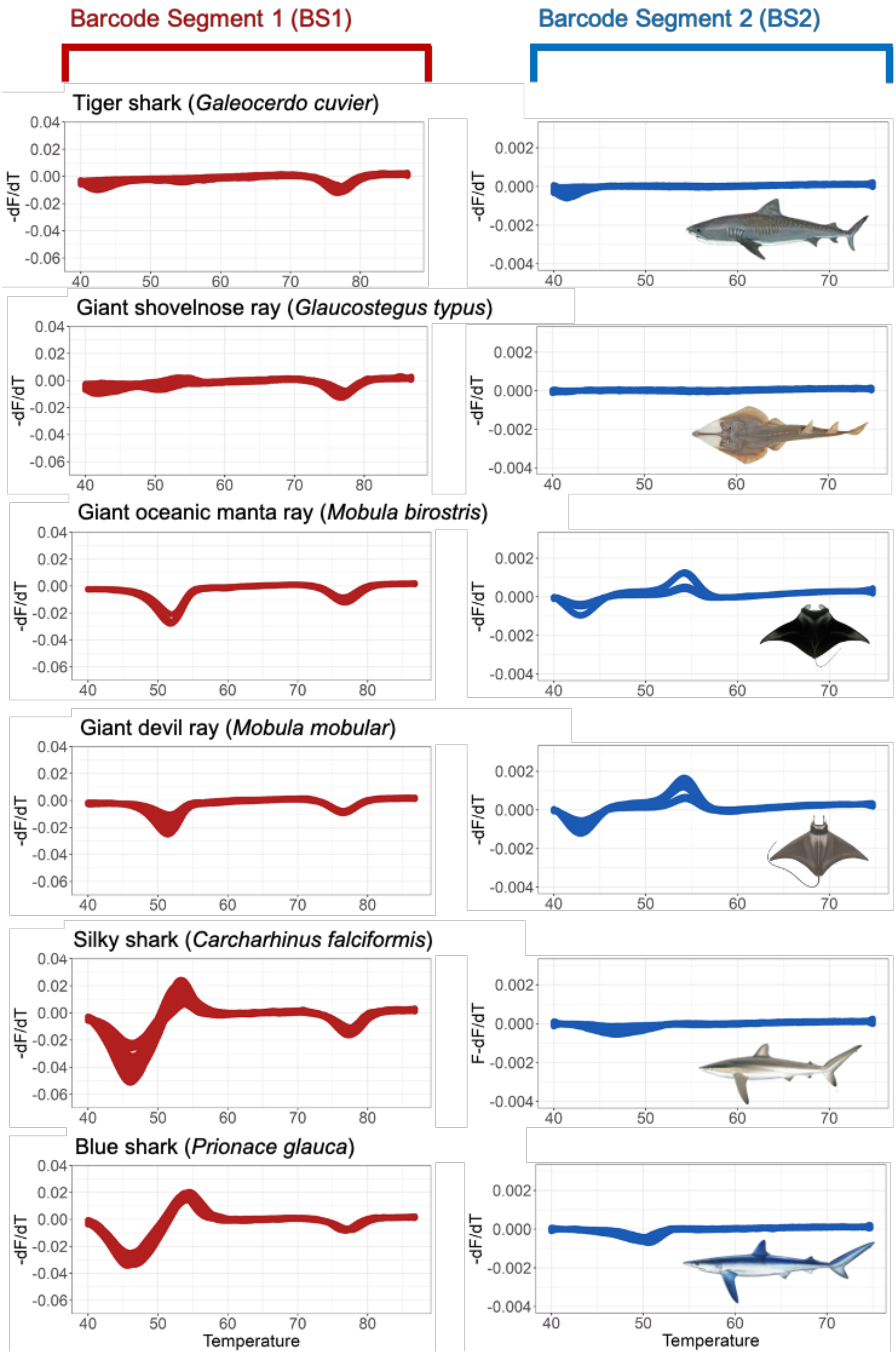
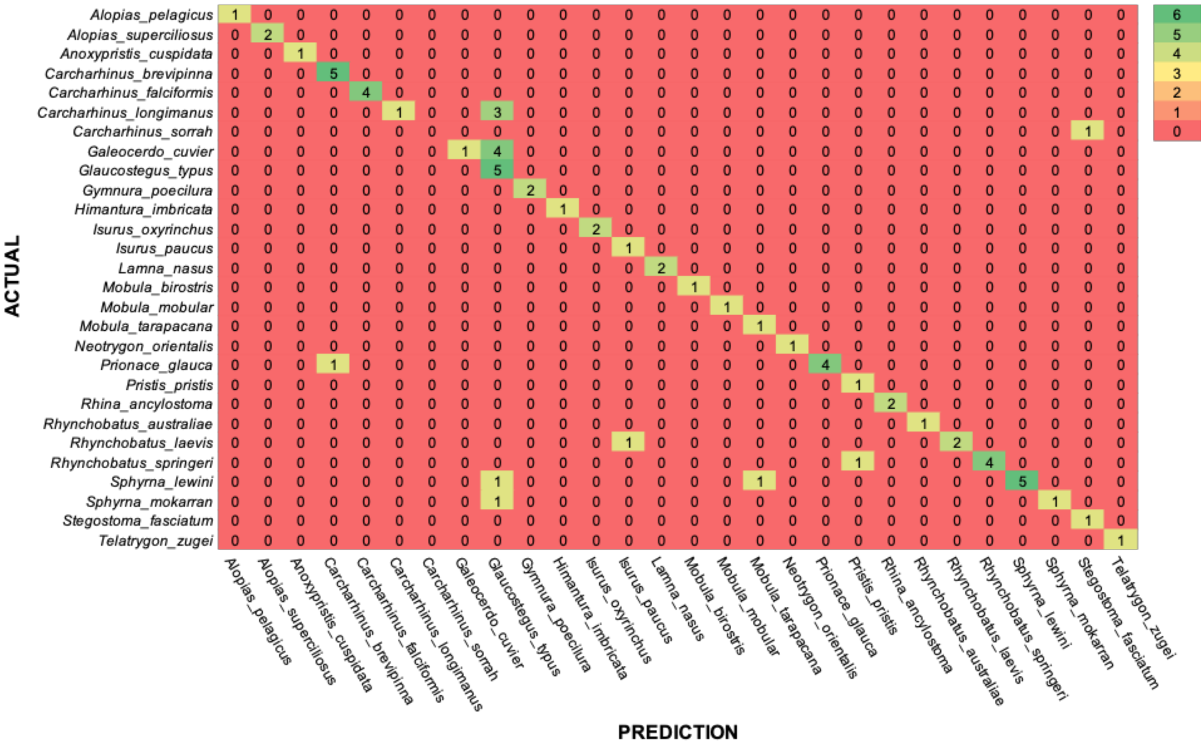


Figure 3.6. Problematic species that visually have similar signature in both barcode segments i.e. tiger shark, giant shovelnose ray, giant oceanic manta ray, giant devil ray, silky shark and blue shark.

3.3.2. Machine learning for species assignment

We transposed data for the training sets and then used fluorescence values at 8,152 temperature intervals (>4,000 per each barcode segment) as variables and identified variable importance as a key feature for species assignment. We ranked variable states according to their relative importance, scaled importance and percentage of variance explained, for each barcode segment (see **Table S3.5**). We generated 301 potential deep learning models, aiming for high accuracy and minimizing error. The best deep learning model was chosen as the one with the highest accuracy (98.20%;). When the model was applied to melt curve data from the independent specimens, accuracy dropped to 79.41%, with 54 out of 68 specimens correctly assigned (**Figure 3.7**). Mis-assignments were consistent with the species that also proved problematic during visual assessments, i.e. the spinner and blue shark. The model also mis-identified spot-tail shark as zebra shark despite it visually having a unique signature in BS2 (**Figure 3.5**). During the testing, some samples from hammerhead sharks (*Sphyrna* spp.), smoothnose wedgefish (*Rhynchobatus laevis*), and broadnose wedgefish (*Rhynchobatus springeri*) were assigned to the wrong species, even though each of these species had their own unique fingerprint (**Figure S3.2-5**).



Training

Parameter	%
Train accuracy	98.1982
Train RMSE	2.05×10^{-5}
Test accuracy	79.4117647

Testing

Item	Value	%
Total	68	
Correct	54	79.4118
Wrong	14	20.5882

Figure 3.7. A confusion matrix of 28 shark and ray species assignments shows the mismatch between the actual species (y-axis) and the assignment process (x-axis). Dark green means more specimens assigned to the condition, while dark orange represents low value. The model's accuracy during the training and testing stages is also presented.

3.4. Discussion

Within a couple of hours and without the need to adjust the existing FASTFISH-ID^{TM} assay from teleost fish to elasmobranchs, this real-time PCR method offered a portable monitoring tool that reliably enabled the identification of 25 elasmobranch species (20 of which are CITES-listed). The device used to conduct the runs, the MIC, is a convenient portable real-time PCR thermocycler weighing no more than 2 kg and allowing for the simultaneous inspection of 48 specimens per run (Naaum et al., 2021). More importantly, the use of probes targeting mini barcodes with high inter-specific variation offers a universality that other qPCR-based assays do not currently provide, and the automatic amplification of the full COI barcode as part of the same reaction offers downstream opportunities for further in-depth screening, if necessary.

While existing genetic-based monitoring tools continue to be useful in many situations (Shivji et al., 2002, Fields et al., 2015, Cardeñosa et al., 2018, Lin et al., 2021), FASTFISH-ID™ seems poised to significantly expand the horizons of DNA-based control: alongside its speed, portability, and universality, the method exhibits single nucleotide resolution (Rice et al., 2012) which can minimize the risk of similar fluorescent signatures, particularly when more species are added to a reference library (Naaum et al., 2021). This is a particularly compelling argument for its implementation, as CITES lists are likely to continue to expand in the future. Additionally, the amplification of the whole COI universal barcode segment embeds a forensic dimension (Dawnay et al., 2007) that is not necessarily afforded by other portable tools.

A difficulty typically encountered in genetic-based trade monitoring is the handling of processed products, and this is particularly true for elasmobranchs which tend to be heavily processed in a variety of ways (Dharmadi et al., 2019a, Muttaqin et al., 2018). Despite the issues of fragmented DNA due to the effect of various processing techniques (Shokralla et al., 2015), FASTFISH-ID™ shows notable robustness and reliability, with 83.6% of processed samples yielding reliable melt curve profiles (51 of 61 processed samples). Since FASTFISH-ID™ uses real-time PCR and relies on fluorescent signatures, some species display variation in signature amplitude (the variation in peak heights and valley depths) especially when the DNA was degraded, as observed with processed products and displayed by the signature of both hammerhead species on BS2 (**Figure 3.4**). This deviation may be problematic for species assignment, especially when the assignment depends on a deep learning algorithm. The high probability of the features being similar to those of other species caused misassignments. Other issues that may have occurred is variation in the fluorescence signature from the same species. This could be due to single nucleotide polymorphisms (SNPs) within species or possibly to contamination in the case of the BS2 signature of the pale-edged stingray (*Telatrygon zugei*; **Figure S3.5**).

Visual assessment could distinguish 22 species out of 28 with more than half of these (N=17) being CITES-listed. Even in this preliminary phase, the method could therefore readily be applied by inspectors –without the application of computational tools – and reliably reveal cases of illegal activities. Three pairs of species had spectral features that are difficult to distinguish, e.g. these ambiguities were present between tiger shark and giant shovelnose ray, between two species of *Mobula* rays (giant oceanic manta ray and giant devil ray), and between silky and blue shark (**Error! Reference source not found. - Visual**). Thus, it must be acknowledged that the barcode segments have the same sequence of nucleotides and produced similar signatures for those species. The technology was originally designed for bony fish (Naaum et al., 2021), and the database is currently being expanded to various important species that are globally traded as seafood. Yet, the much lower diversity of elasmobranchs (~1/30th that of teleosts) will make any effort to produce spectral reference databases a far less onerous task than that currently encountered with bony fishes. Whilst it has been known that the COI gene is more slowly evolving in chondrichthyans than teleosts (Moore et al., 2011, Naylor et al., 2012), this is seldom a major issue in most DNA barcoding applications (Hobbs et al., 2019, Fields et al., 2018, Griffiths et al., 2013), so an optimised iteration of the FASTFISH-ID™ method is poised to be transformational for elasmobranch conservation and management. A qualitative investigation on the full length of COI sequences (Sanger sequencing results) based on visual and simple comparison (https://www.bioinformatics.org/sms2/ident_sim.html) revealed that for those problematic three pairs of species mentioned above for that particular segment, there is a high degree of similarity in their sequence (70-98%), although this seems unlikely as the method is extremely sensitive and easily distinguishes between sequences that differ by a single nucleotide (Sirianni et al., 2016).

In the absence of an online reference database of elasmobranch fluorescent signatures, machine learning was developed for this study. One of the machine learning applications is pattern recognition (Trentin et al., 2018, Jenrette et al., 2022). Deep learning (also known as deep structured learning) is broadly applied in machine learning applications, especially pattern recognition (Trentin et al., 2018, Jenrette et al., 2022) and has advantages in its flexibility to develop learning styles i.e. supervised, semi-supervised or unsupervised (LeCun et al., 2015, Malde et al., 2019). Deep learning models have been chosen and deployed with independent testing datasets to measure their accuracy. We found that the accuracy of our test model was 79.41%, which is lower than the training accuracy (98.20%; **Table S3.7**), and yet the model could identify similar species that could not be distinguished visually. In fact, the model enabled us to differentiate the two *Mobula* species that have similar signatures in both barcode segments. Machine learning could also recognize silky shark, a problematic species for the authorities as the species belongs to the Carcharhinidae, a diverse family that has plenty of look-alike species. In particular, the silky shark spectral profiles appeared visually indistinguishable from blue shark. However, the new CITES listing agreed during CoP19 added all requiem sharks into Appendix II (including blue shark along with the other 53 species shark from Carcharhinidae family) will make implementing action manageable since requiem sharks make up a large proportion of the products found in the global shark fin trade hubs in China (Cardeñosa et al., 2022). Although international trade in all requiem sharks will now be regulated, a Non-Detriment Finding (NDF; CITES's mechanism that allows certain species listed in Appendix II to be traded with strict quotas) which is specific to each species will still require the capability of identification at the species level.

Five out of 28 species could not be assigned accurately using the model, i.e. between spot-tail and zebra shark as well as mis-assignments among oceanic whitetip shark, tiger shark and giant shovelnose ray (**Error! Reference source not found. – Deep Learning**). Curiously, there were also mis-assignments for species that had quite unique fluorescent signatures. We argue that these mis-assignments could be due to variation in amplitude, where some species actually have similar signatures, but different amplitudes (Cusa, 2021) the cause of which is undetermined, but could be due to degraded DNA. For instance, the signature in BS2 of zebra shark has high amplitude variations that may challenge the model to assign the species (**Figure 3.5**). Increasing training datasets may be required as this should improve the robustness of the model (LeCun et al., 2015), while future re-tailoring of the barcode regions to elasmobranch variation may also remove some of the within-species noise. Despite the assignment problems, when we combine visual and deep learning assignments, we could distinguish 25 out of 28 species, 20 of which are listed in CITES Appendix II.

3.5. Conclusion

FASTFISH-ID offers a potential solution for shark and ray identification by providing a practical and portable platform using a single set of reagents and equipment, blending the speed of real-time PCR and the universality of DNA barcoding. Our evaluation showed that, even without any optimisation for elasmobranchs, FASTFISH-ID has the robustness to identify various elasmobranch products. By combining assignment methods (visual and deep learning), 25 elasmobranch species out of 28 are reliably distinguishable based on the two fluorescent signatures. Machine learning offers a promising framework to run automatic identification in the absence of a reference database. This simple protocol and high portability could help authorities (i.e. fish inspectors, customs and quarantine officers) by providing a testing option for any point in the supply chain. However, the probe hybridization problems (which occurred when the barcode segments have a high degree of mismatches with the designed probes) encountered in seven species prevented the machine learning tool from adequately assigning fluorescent signatures to a given species. Since BS1 failed to hybridize for most of these species, the species assignment in these cases was solely reliant on BS2, which, in many cases also exhibited poor hybridization. To address this issue, it seems that going forward the designing of new probes tailored to elasmobranch sequence variation will be a necessary solution to increase the versatility and reliability of FASTFISH-ID™. An increased set of elasmobranch species may also inflate mis-assignments due to the higher degree of similarity among species in both visual-based or machine learning-based systems. Moreover, we also need to consider sequences variants within species (haplotypes) that may vary due to individuals originating from different geographical locations. There is also limitations in using fully supervised deep learning approaches in the selection of important features from highly variable training sets (e.g. signatures from the two barcode segments) (Hantak et al., 2022). The addition of more species to the database will require more training images. However, with such improvements, this method will help authorities (i.e. fish inspectors, customs and quarantine officers) by providing a single, agile testing option, at any point in the supply chain, to disentangle the complexity of the shark and ray product trade, and ultimately reduce the consequential risk of extinction for these endangered and iconic taxa.

Data and materials availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation. Sample metadata and R scripts are available at https://github.com/andhikaprima/FastSharkID and archived on Google Drive: https://bit.ly/FASTFISH-ID_MS_Supp_Datasets.

Additional information

Supplementary information

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Chapter 4

Shark-dust: High-throughput DNA sequencing of processing residues unveils widespread trade in threatened sharks and rays

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Figure 4.1. Two containers full of shark and ray products (various type of processing) asking for inspection as export requirement.

Abstract

Illegal fishing, unregulated bycatch, and market demand for certain products (e.g. fins) are largely responsible for the rapid global decline of shark and ray populations. Controlling trade of endangered species remains difficult due to product variety, taxonomic ambiguity and trade complexity. The genetic tools traditionally used to identify traded species typically target individual tissue samples, are time-consuming and/or species-specific. Here, we performed high-throughput sequencing of trace DNA fragments retrieved from dust and scraps left behind by trade activities. We metabarcoded ‘shark-dust’ samples from seven processing plants in the world’s biggest shark landing site (Java, Indonesia), and identified 61 shark and ray taxa (representing half of all chondrichthyan orders), half of which could not be recovered from tissue samples collected in parallel from the same sites. Importantly, over 80% of shark-dust sequences were found to belong to CITES-listed species. We argue that this approach is likely to become a powerful and cost-effective monitoring tool wherever wildlife is traded.

Keywords: Elasmobranchs, trade Monitoring, DNA metabarcoding, environmental DNA, Indonesia

4.1. Introduction

Continued and increasing anthropogenic stressors have devastated habitats and wildlife across the globe, including the dramatic depletion of sharks and rays (hereafter referred to as ‘elasmobranchs’) (Dulvy et al., 2021). Conservative life-histories (Mardhiah et al., 2019) make elasmobranchs vulnerable to fisheries overexploitation, and their extirpation can destabilise functional diversity and ecosystem structure (Dulvy et al., 2021). Although some elasmobranch fisheries can be sustainably managed (Simpfendorfer and Dulvy, 2017), market demand for high value products, such as fins, liver oil and gill plates, typically leads to overexploitation of elasmobranch resources (Dulvy et al., 2021), which is then further fuelled by illegal and unreported catches.

This combination of market demand, over-exploitation, and lack of detail in catch and trade data (Cawthorn et al., 2018) requires effective mechanisms to monitor elasmobranch populations and ensure their sustainable management (Prasetyo et al., 2021). This includes improved catch reporting, special regulations for endangered species (e.g. the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, (Pavitt et al., 2021)), and a range of other transdisciplinary initiatives (Booth et al., 2019). A critical step in this context is the accurate reconstruction of the biodiversity composition of elasmobranch products at landing sites, processing plants, markets and export hubs.

This year, the difficulty of the task has more than tripled, as the number of CITES-listed species has increased from 47 to 151 (CITES, 2022a); yet, species listed in Appendix II can still be traded, by considering viability of exploitation within the Non-detrimental Findings (NDF) framework (Smith et al., 2011). Thus, conservation managers now face a scenario where 14% of the 1,120 described elasmobranch species (nearly one third of which deemed to be under some level of conservation threat, (IUCN, 2021)) can still be traded and substituted for other species under greater restrictions. Understanding and regulating trade in these species is challenging because elasmobranch products are extremely diverse in both their usage and their value, and are processed in a myriad of different ways (Dent and Clarke, 2015). Due to their similarity in appearance and lack of distinctive features in most derivative products, shark and ray species can be deliberately or accidentally mislabelled by those involved in the trade (**Figure 4.2**). This has led to the rapid development of molecular technologies, which progressively made DNA-based inference a staple of wildlife forensics (Domingues et al., 2021). Of these, DNA barcoding (Shivji et al., 2002) and mini- barcoding (Fields et al., 2015) can robustly identify species in fresh and processed samples, while real-time qPCR (Cardeñosa et al., 2018), LAMP-based (But et al., 2020) and universal close-tube barcoding (Prasetyo et al., 2022) assays can detect target species in a matter of hours.

(a) (b)

Figure 4.2. Condition of sample collection for (a) shark-dust from a pile of small dried fins, and (b) tissue sample from a finless juvenile scalloped hammerhead shark whose cephalofoil (the distinctive "face" in this Family, also known as "blade") had been cut.

All these methods require the collection and analysis of individual specimens, which is a significant limitation when large volumes of samples, across many locations, must be inspected in a limited timeframe (Prasetyo et al., 2021). Recent advances in next generation sequencing (NGS) have shaped the transformation of general DNA barcoding (Hebert et al., 2003) into a technique that allows the simultaneous identification of multiple taxa from an inordinate mixture, known as DNA metabarcoding (hereafter referred to as just 'metabarcoding') (Riaz et al., 2011). These principles have been broadly applied to analysing environmental DNA (eDNA) samples – trace DNA fragments left behind by organisms in water, soil and air , an approach that effectively complements, and in some cases surpasses, traditional monitoring (Boussarie et al., 2018, Aglieri et al., 2021). Such developments are unlocking novel applications in trade monitoring, allowing bulk mixtures to be analysed and tackling the limitations of existing tools.

Here we propose a novel metabarcoding application, by targeting seven key shark and ray trading hubs in the island of Java, Indonesia, the top elasmobranch-landing country in the world. We used high-throughput metabarcoding to screen the by-products of processing plant activities (which we term 'shark-dust') and compare them with single-specimen barcoding. This unconventional application is poised to minimize labour requirements, enhance the detection of species that are not visible at the time of inspection, and be implemented globally.

4.2. Material and methods

4.2.1. Study sites

Indonesia's geographical location and its vast and complex coasts make it a unique and emblematic marine megadiversity hotspot. Between 2007 and 2017, Indonesia was the top elasmobranch landing country (Okes and Sant, 2019) but export statistics revealed substantial knowledge gaps and inaccuracies (Prasetyo et al., 2021). Here we targeted seven locations across cities on Java Island, the most populous island in Indonesia (**Figure 4.3**) and the main export hub for various export commodities, including elasmobranch products. The locations included elasmobranch processing plants (PP), export hubs (EH) and an inspector station (AU).

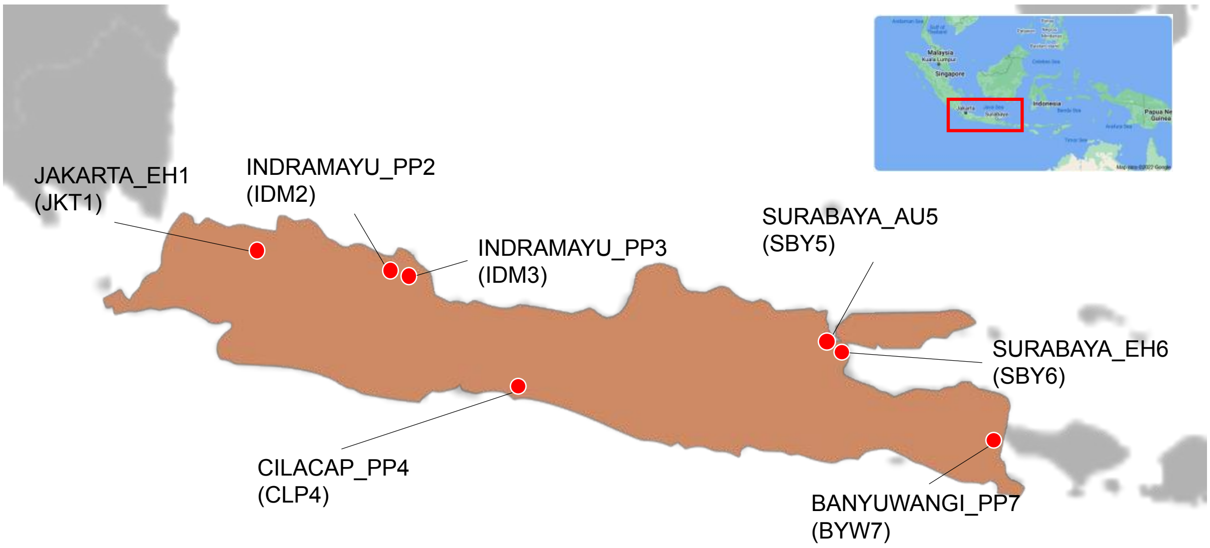

Figure 4.3. Sampling locations across Java Island, Indonesia. Locations are labelled with long and short codes to facilitate identification in subsequent figures.

4.2.2. Sample collection

Dust and tissue samples were collected from January to February 2020. We collected two sets of samples: first, we gathered 28 mixtures of residual material from floors and surfaces where shark products were processed, sorted, and stored for later shipping, henceforth referred to as "dust" samples (**Table S4.1**); then, we selected 183 tissue samples from individual specimens (**Table S4.2**). Replicated samples (4 ± 3 samples) were collected in seven locations representative of Indonesia's processing, export, and regulatory activity. About 10 grams of dust were scooped and stored at room temperature in sterilised 5 ml Click-Seal flat bottom tubes without a preservative. From the same location, about 10g of tissue was collected from individual specimens opportunistically found at the sites without considering the type of product (from fresh to processed products). The tissue was then stored in 2.0 mL screw-cap microcentrifuge tubes, submerged in 90% ethanol and stored at 4°C. Laboratory work and bioinformatics are briefly explained at **Figure 4.4** and detailed below.

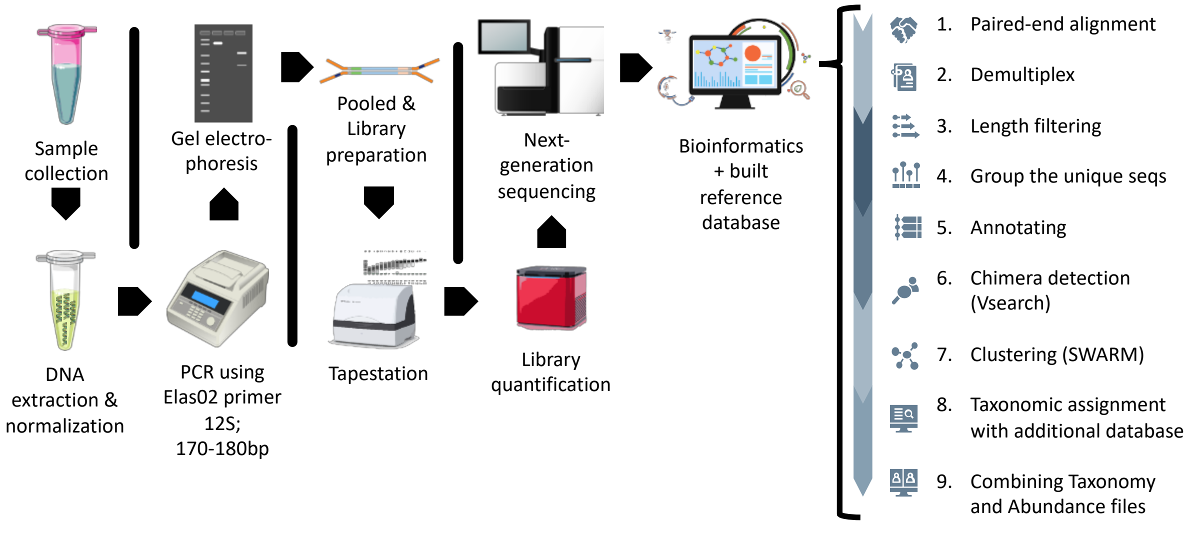

Figure 4.4. Workflow schematic from wet laboratory activities to bioinformatics pipeline of dust metabarcoding.

4.2.3. DNA extraction

DNA was extracted from all samples (dust and tissue samples) following the Mu-DNA protocol for tissue samples (Sellers et al., 2018) with an overnight incubation and a final elution volume of 100 µl. All surfaces were sterilised with 50% bleach and then washed with 70% ethanol, in-between and after extracting each sample, to reduce the risk of cross-contamination. Further measures to avoid contamination included: the use of two separate clean rooms for extraction of dust and tissue, and all the dust laboratory work (from extraction to sequencing) was conducted prior to handling the tissue samples. Dust samples were stored in the sealed bag at room temperature and were handled using sterile instruments. The NanoDrop^{TM} 2000/2000c Spectrophotometers were used to quantify DNA extractions.

We also processed 183 tissue samples from the same locations where dust samples were collected. Tissue samples were extracted similar to the dust samples, but the tissue samples needed to be ground/cut into small sizes before being incubated overnight at 55°C on the thermomixer with a medium mixing frequency. DNA concentrations ranged from 1.5 ng/µl to 407 ng/µl. All DNA extractions were subsequently diluted in molecular grade water down to 10–15 ng/µl for PCR.

4.2.4. Polymerase Chain Reaction (PCR)

Dust-derived DNA was diluted to 10-15 ng/µl prior to DNA amplification. Given that dust was sampled from the floor, an elasmobranch-specific 12S marker was selected to avoid non-target amplification, as the use of a COI-based marker would likely lead to the vast majority of reads coming from other organisms (Collins et al., 2019). The set of Elas02 primer pairs (Elas02-F, 5′-GTTGGTHAATCGTGCCAGC-3′; Elas02-R, 5′-CATAGTAGGGTATCTAATCCTA-GTTTG-3′) was used to target a ~180 bp amplicon from a variable region of the 12S rRNA mitochondrial gene (Miya et al., 2015, Taberlet et al., 2018). This primer sets then were arranged into 32 different combinations of forward and reverse MID tags. These PCR plates constitutes a library of 28 samples, two PCR blanks and positive control (North Atlantic beaked redfish; *Sebastes mentella*). The PCR mix formula was as follows: A total volume of 24 µl included 12.5 µl Qiagen™ Multiplex PCR kit, 1 µl of the 5 µM pre-mixed forward and reverse primers (Macrogen™), 3 µl of a standardised amount (10-15 ng/µl) of DNA, and 7.5 µl sterile water. The PCR profile included a 15-minute initial denaturing step at 95 °C, 40 cycles at 94 °C for 1 minute, 59 °C for 30 seconds, 72 °C for 1 minute and a 5-minute final extension step at 72 °C. The library was amplified in triplicate to minimize amplification stochasticity, but these PCR replicates were not individually barcoded (i.e. triplicates were pooled into a single representative sample). After PCR, each replicate was visually examined on a 1.2% agarose gel, stained with GelRed® Nucleic Acid Gel Stain (**Figure S4.1**). Each well received 2 µl of sample and a 100 bp ladder Invitrogen™ was included in the gel for reference. Then, the triplicates were pooled for quantifying and bead cleaning.

The sequencing of individual tissue samples followed the metabarcoding framework and was termed 'high-throughput barcoding'. A set of 24 Leray-XT primer pairs targeting a ~313 bp amplicon from a region of the COI mitochondrial gene (Wangensteen et al., 2018) was arranged into 200 different combinations of forward and reverse MID tags. Samples were distributed amongst 9 PCR plates. These 9 PCR plates were divided into three (3) libraries. The PCR mix was as follows: a total volume of 15 µl included 7.5 µl Qiagen™ Multiplex PCR kit, 2 µl of the 5 µM pre-mixed forward and reverse primers (Macrogen™), 2 µl of a standardised amount (15 ng/µl) of DNA, and 3.5 µl sterile water. The PCR profile included a 15-minute initial denaturing step at 95 °C, 35 cycles at 94 °C for 1 minute, 45 °C for 1 minute, 72 °C for 1 minute and a 5-minute final extension step at 72 °C. Each library consists of 193 samples, 5 blanks and two positive controls. The library was amplified in duplicate, but these PCR replicates were not individually barcoded. The PCR results were examined visually by gel electrophoresis prior pooled into three different libraries for proceeding to the next stage (**Figure S4.2**).

4.2.5. Bead clean and quantifying

Before library preparation (i.e. the ligation of sequencing adapters onto PCR products), a bead clean was performed to purify the pooled PCR products from dust and tissue samples separately. A left-side bead clean was performed using MAGBio HighPrep™ PCR Clean-up System beads at a 1.1 beads:pool ratio, while the tissue libraries were cleaned using a 0.8 beads:pool ratio. The purified library subset was then quantified using Qubit™ broad range (BR) kit (Thermo Fisher Scientific). The success of each cleaning step was verified on an Agilent Tapestation using High Sensitivity screen tapes (**Figure S4.3** and **Figure S4.4a-c**).

4.2.6. Adapter ligation

Pooled dust PCR products were then diluted into 20 ng/µl concentrations. Adapters were ligated using the KAPA Hyper Prep Kit PCR-Free protocol with incubation time at 7 minutes and bead clean at a 0.9 ratio. The NEXTFlex single index sequencing adapters for Illumina platform were ligated onto each library. These adapters have a single 6 bp index. While libraries of tissue samples were used, three (3) unique adapter indices were associated with each library, allowing the 579 samples to be multiplexed into a sequencing run. To verify if adapters have been successfully ligated and no un-ligated adapters remain, each library was examined on the Agilent™ TapeStation using the High Sensitivity screen tapes (**Figure S4.5** and **Figure S4.4d**).

4.2.7. Sequencing

The library was quantified by qPCR using the NEBNext® Library Quant Kit for Illumina sequencing with 4 standards included. The library was then diluted to 6 nM and 4 nM and clarified on another qPCR run using the same protocol. The highest accuracy value (4 nM), then used to proceed to the next sequencing pool. The 4 nM library was sequenced on an Illumina MiSeq run using a 2×150 bp v2 kit. It was loaded at a concentration of 9 pM with a 1% PhiX spike (v3, Illumina) in 700 µl total volume (**Figure S4.6** and **Figure S4.7**).

Tissue sample libraries were additionally diluted into 4 nM and 6 nM prior to pooling. These library pools were then quantified to examine the highest accuracy. The highest accuracy pool (4 nM) contained all 579 samples, 15 blanks and six positive controls. Sequencing of tissue samples was conducted in one Illumina MiSeq run using a 2×300 bp v3 kit. It was loaded at a concentration of 18 pM with a 1% PhiX spike in 700 µl total volume (**Figure S4.8** and **Figure S4.9**). This method is hereafter referred to as "high-throughput barcoding" (HTB).

4.2.8. Building 12S reference database

Preliminary bioinformatics analyses of the dust samples found the existing sequence database had significant gaps and limited resolution to identify several species such as hammerhead sharks (*Sphyrna* spp.) and wedgefishes (*Rhynchobatus* spp.). To overcome this hindrance, 94 samples representing 45 species were chosen (using prior information from 650 bp of COI data; Prasetyo *et al.*, *unpublished data*) and successfully amplified using the Elas02 primer set (see protocol above). The process of PCR, bead cleaning, quantifying, adapter ligation and sequencing of reference samples followed a similar protocol for sequencing the dust samples. This library was sequenced using a MiSeq 2×150 bp nano v2 kit and was loaded at a concentration of 9 pM with a 1% PhiX spike-in 700 µl total volume. For the purpose of this study, these new sequences were added to the 12S elasmobranch database, which was last updated in July 2020 (**Figure S4.10** and **Table S4.3)**.

4.2.9. Bioinformatics and statistical analysis

Bioinformatic analysis was carried out using the OBITools metabarcoding package (Boyer et al., 2016) and the taxonomic assignment was conducted using ecotag against a custom reference database (**Figure 4.4**). Briefly, FastQC was used to quality check reads, and determine suitable length trimming. Reads were then trimmed, merged, and individual samples demultiplexed based on their unique MID tags (8 bp). Identical sequences were then collapsed before de novo detection and removal of chimaeras using VSEARCH (Rognes et al., 2016) with a minimum threshold (minh) by 0.90. We performed clustering with the default parameters of Swarm v3 (Mahé et al., 2021) with a local clustering threshold (d) at 1 and assigned the resultant sequences to taxa with ecotag and a manually curated 12S modified database. Following the pipeline, we applied strict filtering steps, that included retention of sequences within the expected size range (140 bp to 190 bp); removal of non-elasmobranch MOTUs (molecular operational taxonomic units); removal of MOTUs with a taxonomic identity of less than 97%. More than 600 MOTUs identified and collapsed with a taxonomic threshold of 70%. A minimum of two reads was required for the presence of a MOTU at a sample. Any remaining taxon that could not be assigned to phylum level in our, mostly, elasmobranch database was manually searched in the NCBI nucleotide database using blastn and was retained if identity was greater than 97%. The read abundance of 28 samples was pooled into 7 locations where they were taken to be compared with the identification using individual tissue samples. While tissue samples sequenced using the Leray-XT primer (COI region) filtered the fragment size between 299 bp and 320 bp and followed similar parameters to the rest. Sample identification was assigned based on the highest number of reads in an individual sample.

To obtain an accurate estimate of occurrence (Deagle et al., 2019) and correct for both the exponential nature of PCR in the dust samples and the unknown bulk of the different species along the processing stages, a square root transformation and relative read abundance (RRA) metric were applied. Sampling effort and sample types were evaluated with species accumulation curves plotted with the R package BiodiversityR (Kindt and Coe, 2005) using the ‘exact’ method. To assess differences in biodiversity between sampling techniques, we converted species detection from both samples to presence-absence data by locations and then calculated one dissimilarity index (Jaccard, for binary MOTU data) with the function 'metaMDS' and the configuration was visualised in scatterplots. We also formally tested differences between shark-dust and tissue samples with PERMANOVA (999 permutations) using the function 'adonis'. Both functions run with the R package vegan (Oksanen et al., 2013). Statistical analyses were performed in the R program environment (R Development Core Team 2012, version 3.6.0). The scripts and dataset associated with the study are provided at: https://github.com/andhikaprima/sharkdust and https://doi.org/10.5061/dryad.nk98sf7wc.

4.3. Results and discussion

4.3.1. Dust metabarcoding analysis

We obtained around 5.6M reads from 28 discrete dust samples. We refined the final dataset to 4,640,239 elasmobranch-only reads, partitioned into 61 MOTUs (**Figure S4.11**, **Figure S4.12**, **Figure S4.13**, **Table S4.4**) belonging to seven different orders: Carcharhiniformes, Lamniformes, Squaliformes, Hexanchiformes, Orectolobiformes, Myliobatiformes, and Rhinopristiformes. Taxonomic assignment successfully identified 54 of the 61 MOTUs to species level, with five assigned to genus level and two only attributable to families.

Nearly 84% of the total reads belonged to 32 CITES-listed taxa, including high profile pelagic bycatch species, such as hammerhead sharks (*Sphyrna* spp.), silky shark (*Carcharhinus falciformis*) and spot-tail shark (*Carcharhinus sorrah*) (**Figure 4.5a**). The scalloped hammerhead shark (*S. lewini*) could be found almost everywhere and was most prevalent in the processing plants in Indramayu (IDM2 and IMD3), Banyuwangi (BYW7), and Surabaya (SBY6). The spot-tail shark, recently added to the CITES list, showed highest read abundance in the Indramayu processing plants (**Figure 4.5b**). Among non-CITES-listed species, tiger shark (*Galeocerdo cuvier*) was the predominant species across sampling locations, followed by zebra shark (*Stegostoma fasciatum*), the Australian weasel shark (*Hemigaleus australiensis*), whitespotted whipray (*Himantura gerrardi*) and spotless smooth-hound (*Mustelus griseus*) (**Figure 4.5c**). These five species contributed about 70% of the non-CITES-listed read count overall, but their relative proportions varied greatly among locations.

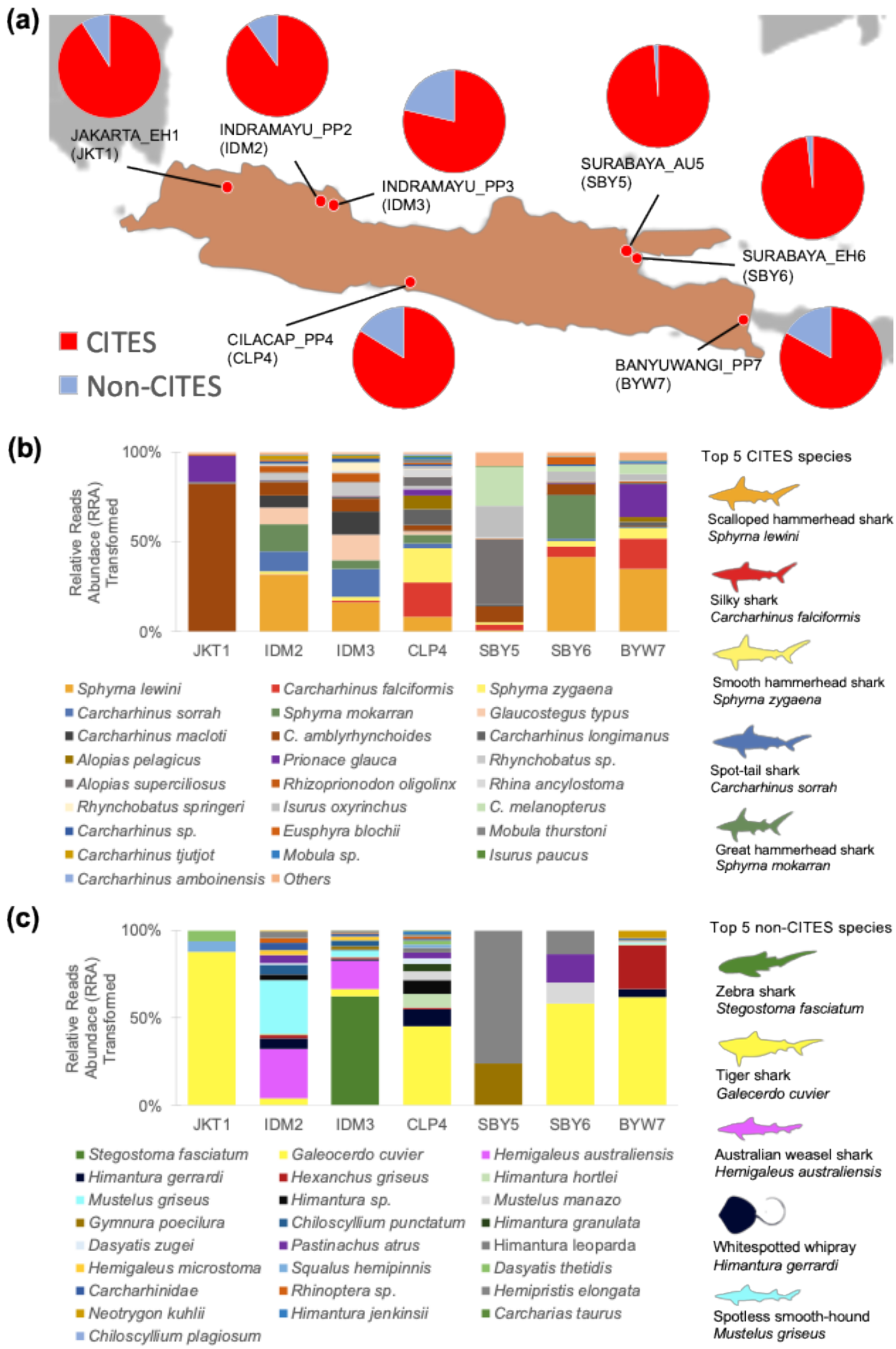

Figure 4.5. CITES and non-CITES listed species composition (in square-rooted read abundance) across sampled locations (a); composition of CITES-listed species (b), and composition of non-CITES-listed species (c). Top-5 species are visualized with silhouettes and same colour in the bar chart. Read abundance values were square-root transformed.

The prevalence and abundance of reads from CITES-listed species detected in dust samples show that these animals continue to be major trade commodities and that monitoring efforts need to be intensified. Such species of conservation concern – primarily pelagic taxa – are found in abundance in processing plants (IDM2, IDM3, CLP4 and BYW7) and exporter warehouses in main export hub cities (i.e. Jakarta and Surabaya (JKT1 and SBY6)). These results amplify earlier indications that CITES-listed species, such as thresher sharks, hammerhead sharks, silky shark, wedgefishes, and guitarfishes, are still being traded in major Indonesian markets (Fahmi et al., 2021) and may still be exported through Non-Detrimental Finding (NDF) mechanisms (CITES, 2022b). In Hong Kong, which is the main destination market, fin products of CITES-listed species are modelled to be ~10% of the overall traded volume (Fields et al., 2017). Based on our results from the world's largest exporter – and the recent expansion of CITES listings – these figures are likely an underestimation. Dust samples also detected several key reef-associated sharks as trade commodities, such as blacktip reef shark (*C. melanopterus*), whitetip reef shark (*Triaenodon obesus*) and sand tiger shark (*Carcharias taurus*). These species play an important part in the equilibria of coral reef ecosystems, which is particularly concerning for Indonesia, where reef-sharks have been driven to near functional extinction (MacNeil et al., 2020). Several mesopredators among the rays were also detected, including Hortle's whipray (*Himantura hortlei*), mangrove whipray (*Himantura granulata*), pale-edged stingray (*Dasyatis zugei*), and bluespotted stingray (*Neotrygon kuhlii*). These species, albeit not controlled under CITES, significantly contribute to trophic interactions in key coastal ecosystems (Flowers et al., 2021); in fact, 90% of non-CITES-listed species detected from dust samples are currently designated as threatened species under the IUCN (International Union for Conservation of Nature) Red List (IUCN, 2021). Therefore, beyond trade enforcement aspects, obtaining information on these taxa is critical for monitoring the impact of exploitation on population dynamics and ecosystem health.

4.3.2. Comparison of species detections from dust and tissue samples

Tissue-based barcoding successfully identified 175 out of 183 samples associated with the locations where dust samples were taken. Specimens were partitioned into 36 taxa, nearly all of which were also detected in the dust samples (**Figure 4.6a**). Overall, we were able to identify more than 70 taxa across methods; however, the dust samples detected 16 more genera than tissue samples and identified 11 unique CITES-listed species (**Figure 4.6a-b, Figure S4.12, Table S4.5**). When sequencing reads from the dust samples were transformed into presence and absence data, species compositions between dust and tissue samples were shown to be significantly different (PERMANOVA: F=3.49, p=0.001; **Figure 4.6c, Table S4.6**). Tissue samples show a greater separation among locations, due to the high-grading bias introduced by the single-specimen approach to sampling (which may also select for more 'notable' samples). Dust samples showed a consistently greater alpha diversity across locations, detecting an average of 31.57 (±16.34) taxa per sample, with tissue samples averaging 11.14 (±6.01), as is also shown by the taxon accumulation curve (**Figure 4.7a**).

Dust metabarcoding has much greater power to unveil a comprehensive portrayal of shark and ray species being traded, for a considerably lower sampling effort (N_{dust}= 28 *vs* N_{tissue}= 175) and less disruption of the processing and trading operations in the visited hubs (**Figure 4.7b-c**). Dust samples revealed some cryptic and rare species, such as winghead shark (*Eusphyra blochii*), pigeye shark (*C. amboinensis*), sand tiger shark (*Carcharias taurus*), smooth hammerhead (*S. zygaena*), knifetooth sawfish (*Anoxypristis cuspidata*), manta and devil rays (*Mobula* spp.). The latter three are hardly ever seen at landing places, given their fully protected status under Indonesia's regulations. These findings mirror the performance of eDNA studies on elasmobranchs from natural environments, which consistently reveal important 'dark diversity' that is missed by pre-existing biomonitoring tools (Boussarie et al., 2018). In this sense, the 'shark-dust' metabarcoding approach can boost and streamline all the biodiversity, fishery, and trade control operations that have up to this point been carried out via earlier-generation DNA monitoring tools.

There were 39 CITES-listed taxa identified in total, with 22 taxa, including thresher sharks (*Alopias* spp.), mako sharks (*Isurus* spp.) and two hammerhead species that are commonly found at landing sites (*S. lewini* and *S. mokkaran*) identified using both dust and tissue samples. Meanwhile, tissue samples revealed one species that is not distributed in Indonesian waters, i.e. porbeagle shark (*Lamna nasus*); but this was a single sample obtained from the exporter's reference collection that was used for education purposes.

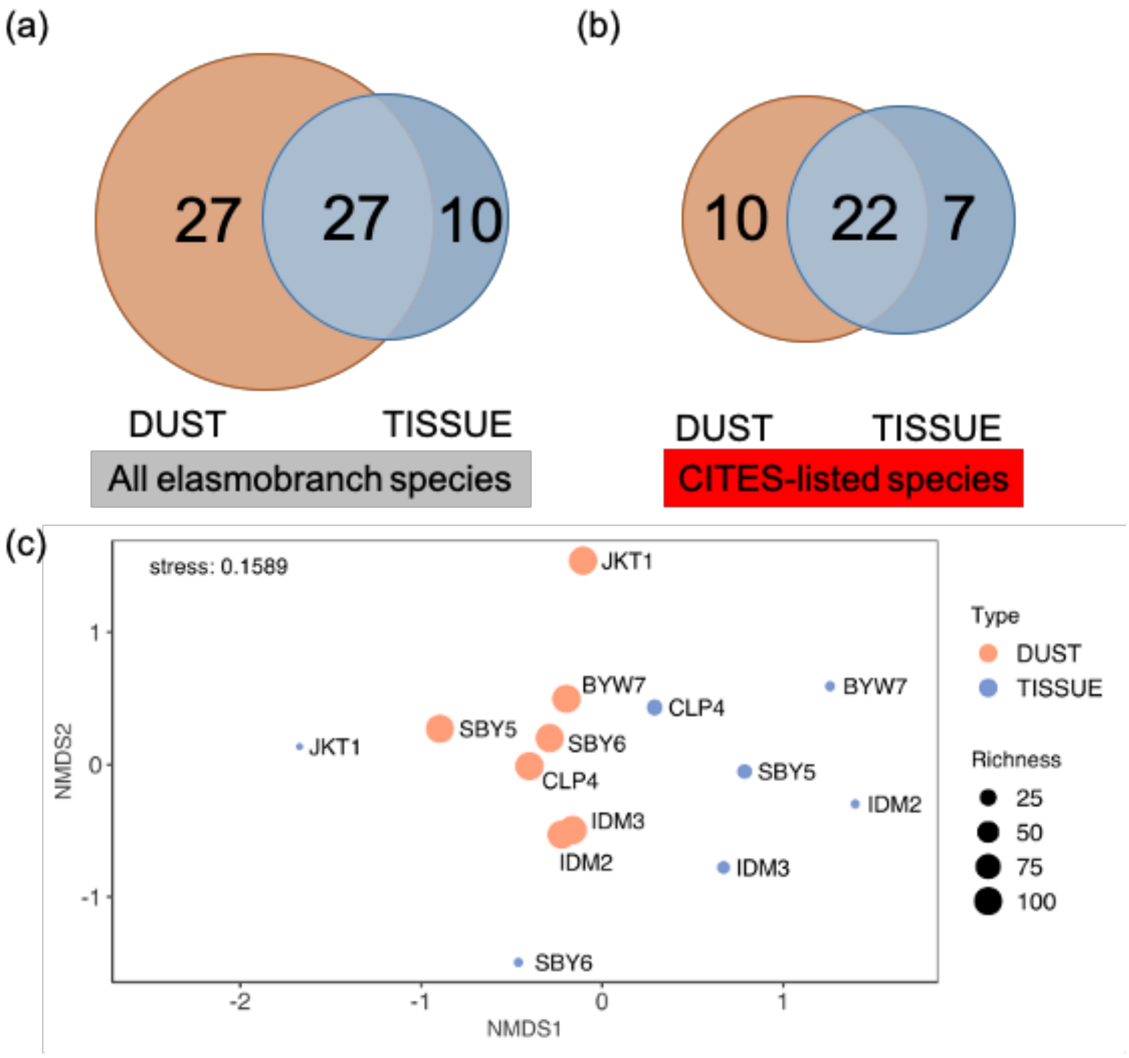

Figure 4.6. Comparison between species recovery from dust and tissue samples; Venn diagrams of all elasmobranch species (a), CITES-listed species only (b), and non-metric multidimensional scaling (nMDS) based on Jaccard similarity index between two sample types in different locations (c). Samples have been pooled into the 7 locations. Nb. Only species-level taxa are considered except for *Mobula* sp. and *Rhynchobatus* sp. as these taxa were detected by dust metabarcoding, despite the 12S marker being unable to discriminate between closely related species in these genera.

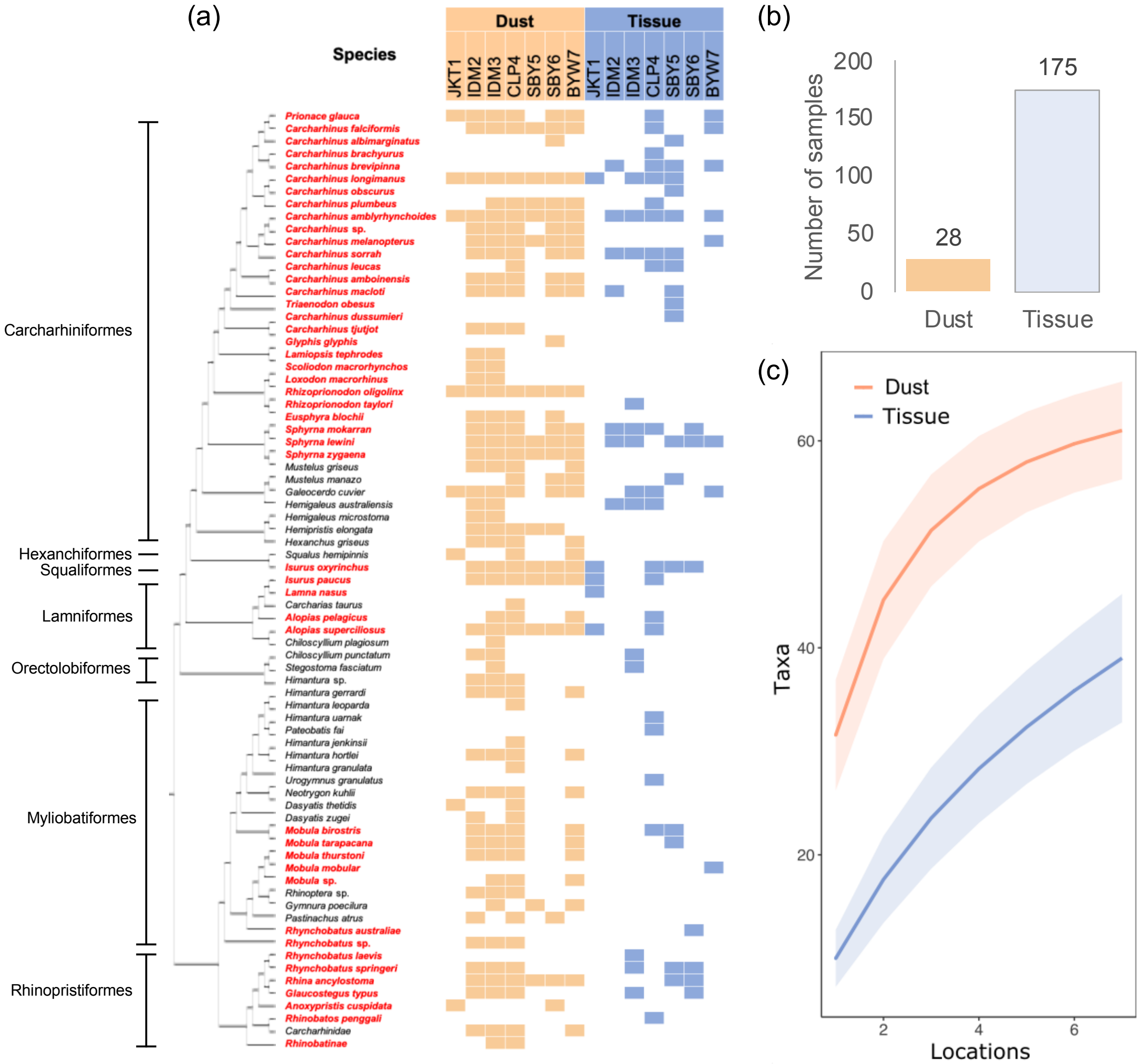

Figure 4.7. The cladogram (a) was generated using FigTree 1.4.4 using NADH2 region sequences (Naylor et al., 2012) from the NCBI database. Colours represent sample type, such as dust samples (ORANGE) and tissue samples (BLUE) for results from each sampling location (b), with CITES-listed species written in RED. Species accumulation curves (c) emphasize the differences in alpha diversity recovery between methods.

4.3.3. A cutting-edge tool for trade monitoring

Our findings showed that trade monitoring using dust metabarcoding expands the reach of traditional barcoding methods. However, seven MOTUs could not be identified to species level from dust samples (**Table S4.7**), including two families and five genera with species listed in CITES appendices, namely wedgefishes (*Rhynchobatus* sp.), devil rays (*Mobula* sp.) and requiem sharks (*Carcharhinus* sp.) and guitarfishes (Rhinobatinae). We had anticipated this issue by developing an additional 12S reference database for our analyses, but recent studies (Miya et al., 2020, Mariani et al., 2021) had already shown that the size (170-180bp) and resolution of the 12S Elas02 fragment will not allow discrimination between some closely related species, as shown for *Rhynchobatus, Mobula*, Rhinobatinae, and also for some species in the polyphyletic genus *Carcharhinus* (Sorenson et al., 2014). Yet, despite these limitations, the marker used remains the most effective metabarcoding tool for elasmobranch identification whilst also avoiding non-target amplification (Collins et al., 2019), and this could be further strengthened through the ongoing expansion of 12S and mitogenomic reference libraries (Collins et al., 2021) and the development of further taxon-specific assays, which may in the future accurately distinguish between the most closely related species.

Another advantage of bulk metabarcoding of processing by-products includes the ability to detect trace DNA in situations where the original tissue source is no longer available, either due to the complexity of trading operations or as a result of deliberate concealment (Challender et al., 2015). This may also allow for coarse estimation of relative volumes traded, which would be impossible through the pain-staking tissue sampling from individual specimens. Finally, dust metabarcoding is also cost-effective: the collection of dry processing residues is easier than collecting and preserving tissue samples, with a much-reduced sample size being sufficient to garner species richness estimates (**Figure 4.7b-c**). Dust residues are technically more susceptible to environmental contamination than tissue samples are, allowing for the detection of DNA traces from species that had previously visited the tested establishment days, weeks, or even months before. Still, this "contamination" is an inherent feature of the approach, which purposely seeks to investigate the biodiversity extracted, processed, and traded through a given hub. Certainly, a formal framework will be required and agreed by key stakeholders (traders, exporters and inspectors) on how to operationally implement shark-dust; possible steps include asking exporters to use brand-new containers for each batch of exports and using appropriate threshold parameters in the bioinformatic workflow.

Recent developments in fast and portable technologies open up new opportunities to run metabarcoding in the field. Our existing approach relies on laboratory equipment, which may be prohibitive in some contexts, especially in developing countries. Optimisation of third-generation sequencing technologies (Johri et al., 2019) will most likely advance *in situ* bulk metabarcoding techniques, enabling a wide range of applications in wildlife forensics and fisheries management and benefiting the global conservation community.

The CITES Secretariat promotes capacity development and the transmission of information and skills between countries in order to "efficiently, reliably, and cost-effectively identify shark items in commerce" (CoP18 Doc. 21.2), including genetic procedures. With a current list of 151 species (CITES, 2022a), which now include over 50 species of requiem sharks (Family Carcharhinidae), over 50 species between wedgefishes and guitarfishes, as well as thresher sharks, hammerheads, mantas/devil rays and freshwater stingrays, the difficulties that countries face in complying with CITES regulations have never been greater. Decades of overexploitation have devastated elasmobranch populations; but the use of trade bans will only be successful in tandem with the implementation of reliable and cost-effective monitoring tools. The present approach based on the residues of shark and ray processing activities should prove momentous for conservation by strengthening legality and traceability, working towards sustainability of elasmobranch populations across the world, and inspiring the design of similar methods to combat a wealth of other illegal wildlife trading activities.

4.4. Conclusion

Decades of overexploitation have devastated elasmobranch populations. The use of trade bans will only be successful in tandem with the implementation of reliable and cost-effective monitoring tools. Our study proposes a new method in commerce traceability from the residues of shark and ray processing where original tissue material is often unavailable. Dust metabarcoding, with minimum labour and preservation costs, and a remarkably reduced sample size, is sufficient to unveil traded biodiversity, while also gauging figures of relative volumes processed or traded at a given node of the supply chain. Such an approach should prove momentous for shark and ray conservation, by strengthening legality and traceability to ensure sustainability of elasmobranch populations across the world and could inspire the design of similar methods to combat a wealth of other illegal wildlife trading activities.

Data and materials availability

Indonesia shark and ray DNA barcodes (Elas02 fragment) have been uploaded to the NCBI Short Read Archive (SRA) under BioProject accession number PRJNA850687; and are provided. Raw sequence data OTU (presence/absence), taxa, sample metadata, bioinformatics pipeline and R scripts are available at https://github.com/andhikaprima/sharkdust and archived on Dryad: https://datadryad.org/stash/share/KKqbVy1Rf9grLEpnx_3KmW3ZnZI5ZXsm-oB24BRt_z8.

Additional information

Supplementary information

Figure S4.1. Gel electrophoresis was used to validate the PCR products of dust samples, which were amplified using the Elas02 primer.

Figure S4.2. Gel electrophoresis was used to validate the PCR products of dust samples, which were amplified using the Elas02 primer.

Figure S4.3. Before (a) and after (b) bead cleaning of dust's pool library on an Agilent^{TM} tapestation.

Figure S4.4. Before and after bead cleaning of tissue’s pool library 1-3 (a-c) and adapter ligation (d) on an Agilent^{TM} tapestation.

Figure S4.5. Adapter ligation of dust's pool library on an Agilent^{TM} tapestation

Figure S4.6. Final library quantification (preparing Illumina MiSeq^{TM} Pool) using the NEBio Quant kit of dust's pool library on the Biomolecular Systems’s Magnetic Induction Cycler^{TM} (MIC).

Figure S4.7. The run and lane metrics from the Illumina MiSeqTM sequencing machine of a dust library.

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Chapter 5
General discussion

Figure 5.1. Inspector manually checking suspicious products of CITES-listed species from processed and mixed small fin products which destined for export.

Anthropogenic impacts on the functional diversity of marine megafauna, their ripple effects on ecosystem structure (Pacoureau et al., 2021, MacNeil et al., 2020), and a greater awareness of the value of marine predators when alive (Mustika et al., 2020) have led to increased global attention to shark conservation. Despite the fact that some elasmobranch fisheries are capable of being managed in a sustainable manner (Simpfendorfer and Dulvy, 2017), the high demand for shark and ray products leads to overexploitation (Clarke et al., 2006, Dulvy et al., 2014). Trade restrictions are one measure to slow the rapid decline of these populations, such as international binding bodies, i.e., CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). With 151 species currently listed as endangered or threatened (CITES, 2022a). This number includes more than 50 species of requiem sharks (Family Carcharhinidae), more than 50 species between wedgefishes and guitarfishes, and also thresher sharks, hammerheads, manta/devil rays, and freshwater stingrays. These listings account for just 14% of the 1,120 species that have been described; nonetheless, over one third of these species are considered to risk some degree of conservation risk (IUCN, 2021). The major goals of this study were to (1) reconstruct the current status of shark and ray trade flow in Indonesia; (2) examine the application of existing techniques for universal and rapid identification of individual shark products and (3) examine novel molecular applications to enhance the detectability of restricted shark products. Ultimately, these efforts could help conserve endangered shark and ray populations by improving trade monitoring capabilities and tackling illegal trade, especially in Indonesia where the high landing volume of sharks and rays makes it extremely difficult to monitor controlled species (Okes and Sant, 2019).

5.1. Discrepancy in trade monitoring

The investigation into shark and ray trade in and out of Indonesia found significant inadequacies in existing trade statistics for the nation that lands the world's largest volume of elasmobranchs. Those inadequacies are reflected in four divergence issues, namely: (1) the volume gap between landing and export; (2) the information gap between main landing site and main supplier at the domestic level; (3) the volume gap between export and reported import by trade partners and (4) the impression gap between fisheries policy and bycatch reduction.

Within 10 years (2010–2019), the volume exported by Indonesia was insignificant compared to the total landing values, which may indicate significant domestic consumption. The mismatch between landing and export numbers, the failure to accurately divide landings into local and foreign components (Dent and Clarke, 2015), and the low taxonomic granularity of catch (and trade) compositions are significant difficulties confronting the world's socio-ecological systems. This is crucial in densely inhabited, developing and biodiverse places like Indonesia. The high volume of landings at several of the main landing sites (raw products), i.e., the North Natuna Sea (FMA 711) and Java Sea (FMA 712), were not identified as the main sources of trade commodities. Instead, Bali and Papua provinces were the main suppliers to feed export hubs in the main cities, such as Jakarta and Surabaya. This discrepancy should highlight the importance of improving monitoring resolutions and resolving the dispute between fisheries and trade statistics. We also found that there was a substantial mismatch between exports of elasmobranch fin and meat products and the corresponding figures reported by countries importing from Indonesia. This may indicate illegal trading activities.

This inaccuracy phenomenon is reported globally for CITES and non-CITES specimens and may be improved by strengthening collaboration and enhancing capacity development (Pavitt et al., 2021). CITES regulations actually have a positive impact on management and conservation of elasmobranchs in Indonesia and mainly improve governance and market aspects, as well as small positive influences on fisheries, stock and sociocultural aspects (Friedman et al., 2018). CITES implementation with sufficient understanding of socio-ecological systems may improve the effectiveness of the framework (Thomas-Walters et al., 2020), such as engaging the most impacted stakeholders, i.e., fishers, which tends to leave them with uncertainty and misinformation. Despite the high domestic consumption of shark and ray products in Indonesia, CITES implementation still should be assessed periodically in terms of its efficacy and behavioural changes. Regular monitoring, outreach and education should take place to look into the possibility of a few authorities misinterpreting the CITES provisions by assuming the framework applied to domestic use at the grassroots level, i.e., communities, fishers and traders (Trouwborst et al., 2017). In addition, it is essential to analyse any changes in trading behaviour (i.e., route, volume, and source) that may be contrary to CITES principles (Harfoot et al., 2018). Without adaptations, coastal communities are unlikely to gain from CITES implementation, which may make their business more uncertain. Thus, a viable alternative that maximizes the advantages while reducing the costs is necessary for communities that rely on CITES species (Lavorgna et al., 2018).

5.2. DNA-based tools to improve trade monitoring

With the wildlife trade's destructive impact across the tree of life (Scheffers et al., 2019), numerous tools have been used for tracking other CITES-listed commodities, such as monitoring online wildlife trade (Sung and Fong, 2018), visual identification using deep learning of wood specimens (Olschofsky and Köhl, 2020), near infrared spectroscopy for wood identification (Braga et al., 2011), timber identification using stable isotopes (Kagawa and Leavitt, 2010), cultured fish identification using proteomic approaches (Forné et al., 2010), and of course including molecular approaches highlighted previously. These molecular methods have many advantages, especially for monitoring CITES-listed commodities where key visual identification features have disappeared (Domingues et al., 2021). DNA barcoding is broadly implemented to reveal seafood mislabelling and food fraud in various nations (Cawthorn et al., 2018), including elasmobranch specimens (Shivji et al., 2002, Cardeñosa et al., 2018a) and other CITES-listed commodities (Chen et al., 2015, Ewart et al., 2021). DNA Those methods still required sequencing, which inflates processing time and cost. real-time PCR was developed to tackle this by producing a signature and allowing for rapid identification. This approach has been demonstrated to detect several CITES-listed species in a single run tube, such as the Multiplex real-time PCR assay (Cardeñosa et al., 2018b) and Multiplex LAMP (Lin et al., 2021) using species-specific assays that reveal the species in a matter of hours. But those approaches will be problematic when inspection needs to deal with multiple types of products from different species, across many locations within a limited timeframe to investigate species compositions. In the future, further ambitious proposals submitted to CITES will likely increase the number of 'controlled' species, which may be problematic for methods that rely on species-specific assays.

FASTFISH-ID offers the solution to deal with the limitation of species-specific assays by developing universal probes with high flexibility of target sequences (Naaum et al., 2021) and distinguishing the species by comparing two signatures that were originally developed for bony fishes. This technology allows us to visually identify 82% of 28 species (22 species) from tissue samples based on their two unique barcode segments within 2.5 hours (real-time PCR stage only). There were species that had unique fluorescent signatures in both barcode segments, such as pelagic thresher and bigeye thresher. However, some species, such as zebra and spot-tail shark, have similar signatures in barcode segment 1 (BS1) but can be distinguished by using a signature from another barcode segment (BS2). In addition, some species were unable to be identified using both signatures produced by FASTFISH-ID due to high uniformity, such as the giant oceanic manta ray and giant devil ray. It was also noticed that some species failed to hybridise consistently or at all, as only signatures from "ThermaMark" appeared in BS1, i.e., shortfin mako shark, oceanic whitetip shark and porbeagle shark. Species assignments using machine learning (a deep learning algorithm) revealed an accuracy of 79.41% (23 species of 28 species). Similar problems with species assignments based on visual assessment are reiterated by machine learning. The high degree of similarity among features in both signatures was problematic for deep learning to differentiate certain species. Despite the assignment challenge, we could differentiate more species (25 species) if we integrated visual and deep learning assignment by addressing the assignment problem between spot-tail and zebra shark using visual evaluation. Twenty of these distinct species were CITES-listed species.

Due to the fact that FASTFISH-ID was predicated on a region of the gene COI, it may be difficult to identify elasmobranchs without the whole barcode/gene instead of depending on very short sequences. In chondrichthyans, the whole length of the COI fragment evolves more slowly, making it impossible to discriminate among certain closely related species that are known to be monophyletic (Moore et al., 2011, Naylor et al., 2012). Similar concerns have been noted in the design of primers for metabarcoding extra-organismal DNA extracted from environmental materials, where the COI primer mostly amplified nontarget taxa (Collins et al., 2019). Moreover, adding more species into the database could possibly inflate the problems and reduce the deep learning accuracy. Designing a new probe may be one of the feasible solutions to increase the versatility of FASTFISH-ID, such as: increasing the length of the targeted barcode segment within the COI region (Collins et al., 2019), adding extra barcode segments and using other barcode regions (Naylor et al., 2012, Feitosa et al., 2018, Miya et al., 2015).

Considering the limitations of high dependency on primer design and visible individual tissue samples, we developed an additional genetic-based monitoring tool to improve practicality. The tool is designed to deal with a rigid primer dependency, a large volume of samples across many locations, and a limited timeframe to estimate species composition and detect illegally traded species. Recent developments in technology allow unimaginable advancement of genetic approaches, including massive progression in DNA barcoding, from traditional single DNA barcoding (Hebert et al., 2003) to massive parallel sequencing of complex bulk samples (metabarcoding) (Riaz et al., 2011). This principle is broadly applied to the analysis of environmental DNA (eDNA); where DNA is extracted from environmental samples such as air, water or soil (Ficetola et al., 2008). This application is generally applied to assess biodiversity for which morphological identification and curation is not practical (Boussarie et al., 2018, Liu et al., 2021). Those practicalities have the potential to improve trade monitoring in situations where trade commodities were highly mixed (Staats et al., 2016), in large quantities, and/or may not be visible through individual tissue sampling. Similar techniques have been implemented to other CITES-listed commodities, such as metabarcoding approaches for detecting restricted orchid species (de Boer et al., 2017) and deep sequencing to assess the components of traditional Chinese medicines (Coghlan et al., 2012).

By using dust samples, the prevalence and abundance of reads from CITES-listed species detected in dust samples (over 80%) raise concerns that these animals continue to be major commodities in the shark and ray trade, including thresher sharks (*Alopias* spp.), mako sharks (*Isurus* spp.) and two hammerhead sharks that are commonly found in landing sites (*S. lewini* and *S. mokkaran*) and may still be exported through Non-Detrimental Finding (NDF) mechanisms (CITES, 2022b). Even with only processing a few samples (28 dust samples), we found more taxa detected (54 species) and 27 of these species could not be recovered from extensive tissue samples collected in the traditional way (175 tissue samples). In the absence of tangible samples, this technique is complementary to others that depend on individual tissue samples and, in certain situations, performs better than those other approaches. Technically, dust residues, unlike tissue samples, may include DNA from species that passed through the tested setting days, weeks, or months previously. Nonetheless, this "contamination" is an essential aspect of the method, which is designed to explore the biodiversity harvested, processed, and sold via a specific hub. This performance unlocked a potential solution to the fundamental problem of the implementation of CITES regulations by member countries to reduce illegal trade, such as product variation, trade flows and mislabelling product. Recent development of reliable and portable technology unlocks further opportunities to run shark-dust metabarcoding in the field and may be suitable in many developing countries (**Figure 5.2**).

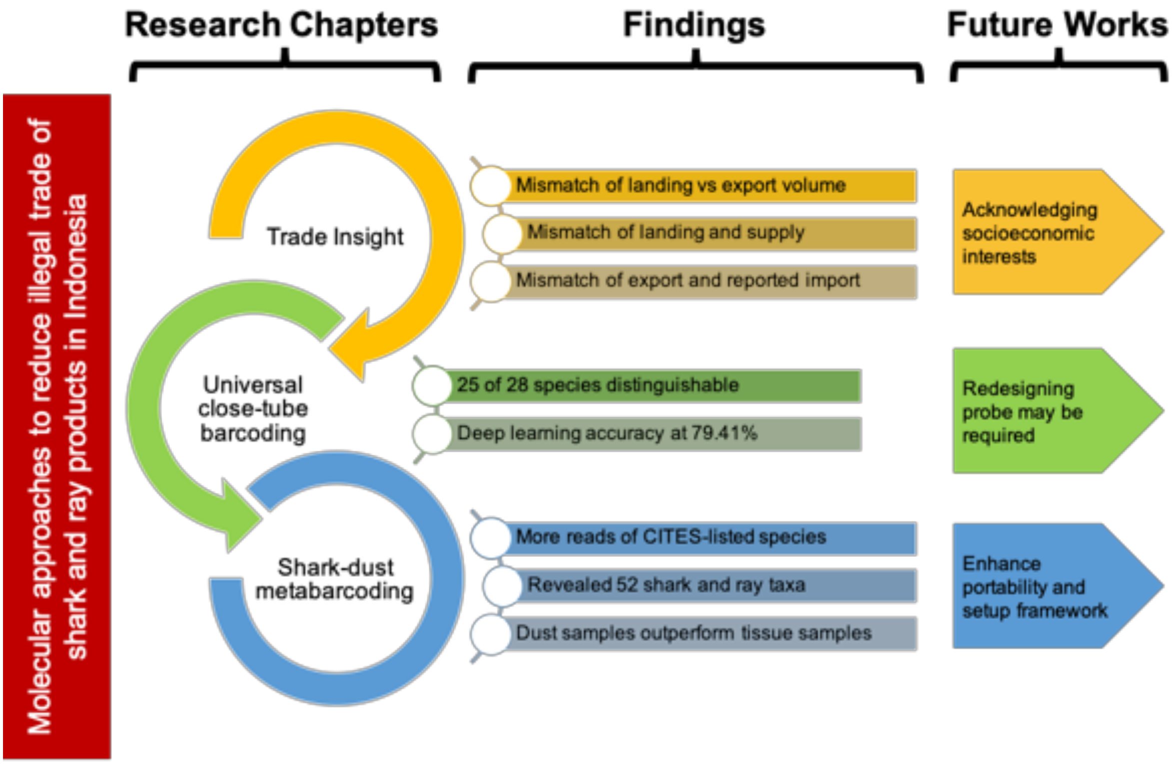

Figure 5.2. Framework of this research: research chapters, findings and future works.

5.3. Future Work

Trade restrictions have been established to counteract the rapid global decline of sharks and rays, which are controlled species under CITES. An increased list of species under CITES will require extra efforts for member countries to put into practice sufficient trade monitoring to ensure the long-term benefit of shark and ray populations. The shark and ray trade are a complicated system in which the socioeconomic benefits outweigh the ecological benefits. An inadequate understanding of the socioeconomic and nuanced aspects of the trade system will have a negative impact on conservation outcomes. A better understanding of trade flows is also necessary to construct comprehensive trade monitoring, such as identifying key hubs, assessing important commodities and investigating mismatches in trade activities.

Genetic tools are practical when the authority is required to inspect various types of processed products, where key identification features are commonly lost. DNA barcoding is the tool commonly used in product authentication and to tackle mislabelling. Recent technology allows DNA barcoding to be run in multiplex and bypass the sequencing stage. However, multiplexing by adding more species-specific assays would mean a sacrifice for the specificity of PCR in favour of a hybridization capture approach that could amplify fragments more consistently. The FASTFISH-ID probe mix offers universality by creating a unique probe with match-mismatch flexibility. An asymmetric PCR technique then enriches excess single-stranded DNA to accommodate probe hybridization. But it was not problem-free. As FASTFISH-ID was originally designed using the COI region to target fishes (teleostei), the application for elasmobranch-based product detection became problematic. Redesigning the probe with other gene regions could improve the technology's reliability and robustness for use in monitoring shark and ray trade.

The previous methods required tangible tissue samples to be processed individually. The huge volume and nature of illicit trade has reduced the capability of those methods in detecting potential illegal products when the inspection time was limited, and the inspection volume was substantial. Shark-dust metabarcoding provides a panacea of product authentication by processing bulk analysis simultaneously from intangible samples. Those techniques significantly reduced sample requirements and contributed to minimizing the cost and time of inspection. However, this technique requires extensive laboratory work that may be inaccessible for some developing countries. Rapid development of portable sequencing technology unlocks the potency of democratizing molecular approaches for broad communities, such as the MinION hand-held sequencer. This potency will allow shark-dust metabarcoding to be run in the field and significantly reduce the analysis time. As this method is prone to contamination, a formal structure will be needed and agreed upon by key stakeholders (traders, exporters, and inspectors) to operationally apply shark-dust.

Due to the alarming extinction rate of shark and ray populations, conservation and management measures should be put in place to ensure the long-term benefit of this population to the ecosystem and human race, such as trade restrictions. A comprehensive understanding of the nature of trade activities will help the authorities arrange a robust inspection framework and acknowledge stakeholder interests. Along with sufficient technology, trade monitoring could be improved by reducing labour costs and inspection time and comprehensively capturing the diversity of species being traded. Sufficient trade monitoring will potentially reduce the risk of illegal trade and ultimately save shark and ray populations worldwide.

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Supplementary material

Supplementary material – Chapter 1

Figure S1.1. Research ethics no. STR1819-45 issued by Science and Technology Research Ethics Panel, the University of Salford, United Kingdom.

Figure S1.2. Research permit no. 251/BRSDM/II/2020 issued by Agency for Marine and Fisheries Research and Human Resources AMFRAD, the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

Figure S1.3. Export permits for CITES-listed specimens no. 00135/SAJI/LN/PRL/IX/2021 was granted under the authority of the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

Figure S1.4. Export permits for non-CITES-listed specimens 127/LPSPL.2/PRL.430/X/2021 was granted under the authority of the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

Figure S1.5. Import permit no. 609191/01-42 from the Animal and Plant Health Agency (APHA), United Kingdom.

Figure S1.1. Research ethics no. STR1819-45 issued by Science and Technology Research Ethics Panel, the University of Salford, United Kingdom.

University of Salford
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4 July 2019

Andhika Prasetyo

Dear Andhika

RE: ETHICS APPLICATION STR1819-45 – Molecular approaches to reduce illegal trade of shark and ray products in Indonesia

Based on the information you provided, I am pleased to inform you that your application STR1819-45 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

Dr Devi Prasad Tumula
Deputy Chair of the Science & Technology Research Ethics Panel

Figure S1.2. Research permit no. 251/BRSDM/II/2020 issued by Agency for Marine and Fisheries Research and Human Resources AMFRAD, the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

KEMENTERIAN KELAUTAN DAN PERIKANAN
BADAN RISET DAN SUMBER DAYA MANUSIA
KELAUTAN DAN PERIKANAN

IZIN PENGOLAHAN DAN ANALISIS DATA DAN SAMPEL PERIKANAN DI LUAR NEGERI
NOMOR 251 /BRSDM/II/2020

Membaca : Surat Permohonan dari Plt. Kepala Pusat Riset Perikanan Nomor: 223/BRSDM.3/TU.210/II/2020 Tanggal 6 Februari 2020 Perihal Permohonan Perpanjangan Izin Pengolahan dan Analisis Data dan Sampel Perikanan di Luar Negeri

Menimbang :
a. bahwa telah dilakukan telaahan, konfirmasi, dan klarifikasi terkait permohonan dimaksud.
b. bahwa kelengkapan dokumen yang dipersyaratkan dalam Peraturan Menteri Kelautan dan Perikanan Nomor 11 tahun 2010 telah dipenuhi.

Mengingat :
1. Undang-Undang Nomor 5 Tahun 1994 tentang Pengesahan *United Nations Convention on Biological Diversity* (Konvensi Perserikatan Bangsa-Bangsa mengenai Keanekaragaman Hayati);
2. Undang-Undang Nomor 18 Tahun 2002 tentang Sistem Nasional Penelitian, Pengembangan dan Penerapan Ilmu Pengetahuan dan Teknologi;
3. Undang-Undang Nomor 31 Tahun 2004 tentang Perikanan sebagaimana telah diubah dengan Undang-Undang Nomor 45 Tahun 2009;
4. Peraturan Pemerintah Nomor 41 Tahun 2006 tentang Perizinan Melakukan Kegiatan Penelitian dan Pengembangan Bagi Perguruan Tinggi Asing, Lembaga Penelitian dan Pengembangan Asing, Badan Usaha Asing dan Orang Asing;
5. Peraturan Pemerintah Nomor 30 Tahun 2008 tentang Penyelenggaraan Penelitian dan Pengembangan Perikanan.

Memberikan izin kepada

Penyelenggara litbang pengirim : Andhika Prima Prasetyo, M.Sc.

Penanggungjawab kegiatan litbang pengirim : Ir. Andi Rusandi, M.Si. / Direktur Konservasi dan Keanekaragaman Hayati Laut

Alamat Penyelenggara litbang pengirim : Jl. Medan Merdeka Timur No.16 Jakarta 10110, Indonesia

Jenis data dan sampel yang akan dikirim : --terlampir--

Jumlah sampel : --terlampir--

UNTUK MELAKUKAN PENGOLAHAN DAN ANALISIS DATA DAN SAMPEL PERIKANAN DI LUAR NEGERI

Penyelenggara litbang penerima : *School of Environment and Life Sciences, University of Salford, Manchester, United Kingdom*

Penanggung jawab kegiatan litbang penerima : Prof. Stefano Mariani dan Dr. Joanna Murray

Alamat penyelenggara litbang penerima : *The Cresent Salford, M5 4WT, United Kingdom*

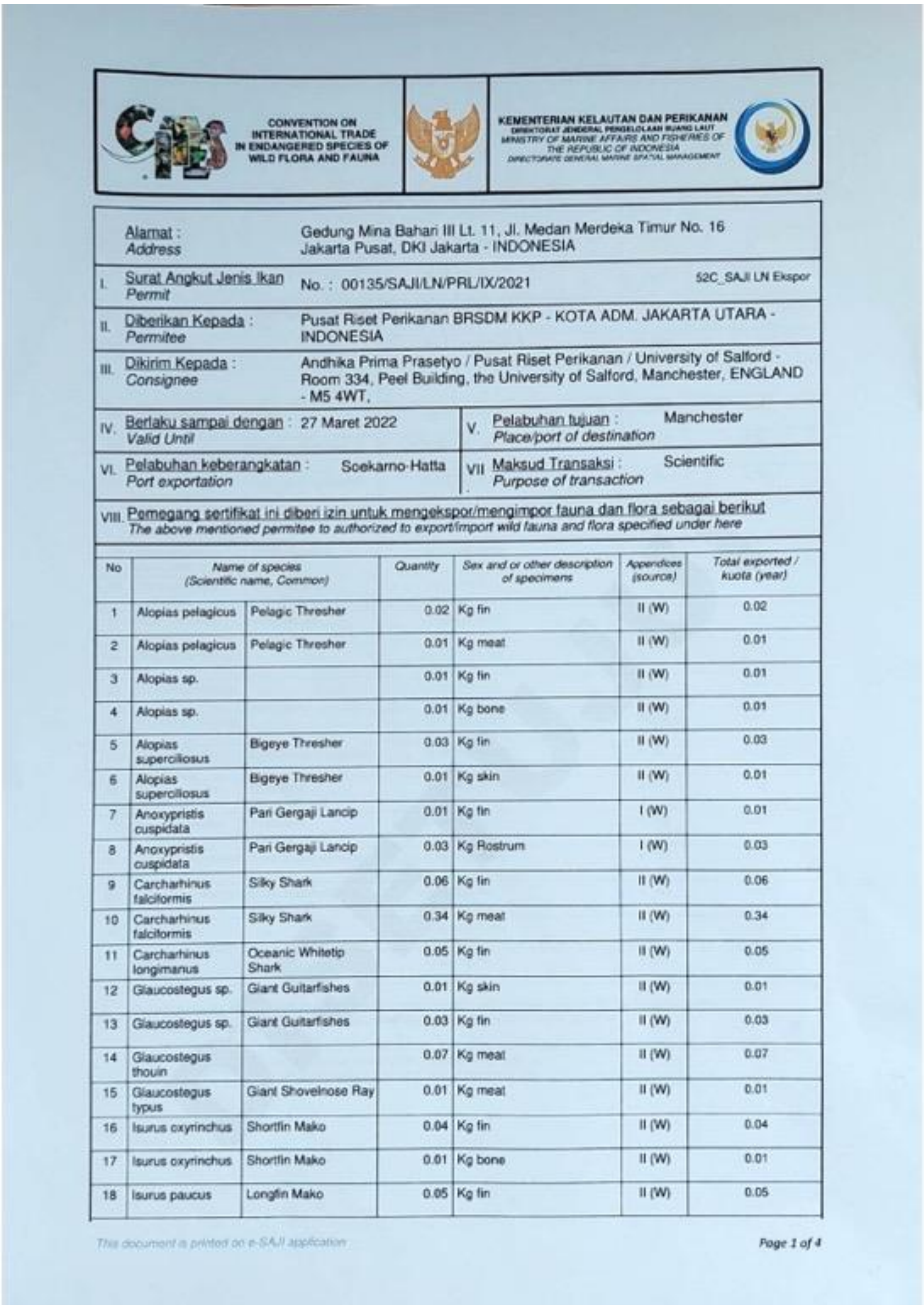
Lokasi pengolahan dan analisis data dan sampel : *School of Environment and Life Sciences, University of Salford, Manchester, United Kingdom*

Jangka waktu izin : 2 (dua) bulan sejak diterbitkan

Dikeluarkan di Jakarta,
Pada tanggal 10 Februari 2020
KEPALA BADAN RISET DAN SDM KELAUTAN DAN PERIKANAN

Prof. Ir. R. Sjarief Widjaja, Ph.D.
NIP. 19630720 198803 1 002

Figure S1.3. Export permits for CITES-listed specimens no. 00135/SAJI/LN/PRL/IX/2021 was granted under the authority of the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.



CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FLORA AND FAUNA

KEMENTERIAN KELAUTAN DAN PERIKANAN
DIREKTORAT JENDERAL PENGELOLAAN RUANG LAUT
MINISTRY OF MARINE AFFAIRS AND FISHERIES OF THE REPUBLIC OF INDONESIA
DIRECTORATE GENERAL MARINE SPATIAL MANAGEMENT

Alamat : *Address*	Gedung Mina Bahari III Lt. 11, Jl. Medan Merdeka Timur No. 16 Jakarta Pusat, DKI Jakarta - INDONESIA	
I. Surat Angkut Jenis Ikan *Permit*	No. : 00135/SAJI/LN/PRL/IX/2021	52C_SAJI LN Ekspor
II. Diberikan Kepada : *Permitee*	Pusat Riset Perikanan BRSDM KKP - KOTA ADM. JAKARTA UTARA - INDONESIA	
III. Dikirim Kepada : *Consignee*	Andhika Prima Prasetyo / Pusat Riset Perikanan / University of Salford - Room 334, Peel Building, the University of Salford, Manchester, ENGLAND - M5 4WT,	
IV. Berlaku sampai dengan : *Valid Until*	27 Maret 2022	V. Pelabuhan tujuan : *Place/port of destination* Manchester
VI. Pelabuhan keberangkatan : *Port exportation*	Soekarno-Hatta	VII Maksud Transaksi : *Purpose of transaction* Scientific

VIII. Pemegang sertifikat ini diberi izin untuk mengekspor/mengimpor fauna dan flora sebagai berikut
The above mentioned permitee to authorized to export/import wild fauna and flora specified under here

No	Name of species (Scientific name, Common)		Quantity	Sex and or other description of specimens	Appendices (source)	Total exported / kuota (year)
1	Alopias pelagicus	Pelagic Thresher	0.02	Kg fin	II (W)	0.02
2	Alopias pelagicus	Pelagic Thresher	0.01	Kg meat	II (W)	0.01
3	Alopias sp.		0.01	Kg fin	II (W)	0.01
4	Alopias sp.		0.01	Kg bone	II (W)	0.01
5	Alopias superciliosus	Bigeye Thresher	0.03	Kg fin	II (W)	0.03
6	Alopias superciliosus	Bigeye Thresher	0.01	Kg skin	II (W)	0.01
7	Anoxypristis cuspidata	Pari Gergaji Lancip	0.01	Kg fin	I (W)	0.01
8	Anoxypristis cuspidata	Pari Gergaji Lancip	0.03	Kg Rostrum	I (W)	0.03
9	Carcharhinus falciformis	Silky Shark	0.06	Kg fin	II (W)	0.06
10	Carcharhinus falciformis	Silky Shark	0.34	Kg meat	II (W)	0.34
11	Carcharhinus longimanus	Oceanic Whitetip Shark	0.05	Kg fin	II (W)	0.05
12	Glaucostegus sp.	Giant Guitarfishes	0.01	Kg skin	II (W)	0.01
13	Glaucostegus sp.	Giant Guitarfishes	0.03	Kg fin	II (W)	0.03
14	Glaucostegus thouin		0.07	Kg meat	II (W)	0.07
15	Glaucostegus typus	Giant Shovelnose Ray	0.01	Kg meat	II (W)	0.01
16	Isurus oxyrinchus	Shortfin Mako	0.04	Kg fin	II (W)	0.04
17	Isurus oxyrinchus	Shortfin Mako	0.01	Kg bone	II (W)	0.01
18	Isurus paucus	Longfin Mako	0.05	Kg fin	II (W)	0.05

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Page 1 of 4

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CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FLORA AND FAUNA

KEMENTERIAN KELAUTAN DAN PERIKANAN
DIREKTORAT JENDERAL PENGELOLAAN RUANG LAUT
MINISTRY OF MARINE AFFAIRS AND FISHERIES OF THE REPUBLIC OF INDONESIA
DIRECTORATE GENERAL MARINE SPATIAL MANAGEMENT

19	Isurus sp.		0.01	Kg fin	II (W)	0.01
20	Isurus sp.		0.01	Kg meat	II (W)	0.01
21	Lamna nasus		0.04	Kg fin	II (W)	0.04
22	Manta birostris	Giant Oceanic Manta Ray	0.01	Kg Gill racker	II (W)	0.01
23	Manta sp.		0.01	Kg Gill racker	II (W)	0.01
24	Mobula sp.		0.04	Kg Gill racker	II (W)	0.04
25	Pristis pristis	NULL	0.01	Kg fin	I (W)	0.01
26	Rhina ancylostoma	Bowmouth guitarfish	0.04	Kg fin	II (W)	0.04
27	Rhina ancylostoma	Bowmouth guitarfish	0.02	Kg meat	II (W)	0.02
28	Rhina ancylostoma	Bowmouth guitarfish	0.01	Kg skin	II (W)	0.01
29	Rhynchobatus australiae	White-Spotted Guitarfish	0.17	Kg meat	II (W)	0.17
30	Rhynchobatus australiae	White-Spotted Guitarfish	0.01	Kg fin	II (W)	0.01
31	Rhynchobatus laevis	Smoothnose wedgefish	0.06	Kg meat	II (W)	0.06
32	Rhynchobatus sp.		0.03	Kg meat	II (W)	0.03
33	Rhynchobatus sp.		0.04	Kg fin	II (W)	0.04
34	Rhynchobatus sp.		0.01	Kg bone	II (W)	0.01
35	Rhynchobatus springeri	Broadnose wedgefish	0.16	Kg meat	II (W)	0.16
36	Sphyrna lewini	Scalloped Hammerhead	0.19	Kg meat	II (W)	0.19
37	Sphyrna lewini	Scalloped Hammerhead	0.02	Kg fin	II (W)	0.02
38	Sphyrna mokarran	Great Hammerhead Shark	0.02	Kg meat	II (W)	0.02
39	Sphyrna mokarran	Great Hammerhead Shark	0.03	Kg fin	II (W)	0.03
40	Sphyrna sp.		0.09	Kg meat	II (W)	0.09
41	Sphyrna sp.		0.08	Kg fin	II (W)	0.08

IX. Syarat khusus : *Special conditions*

Tidak sah apabila ada coretan/koreksi: untuk binatang hidup, hanya berlaku apabila pengangkutannya sesuai dengan peraturan IATA untuk satu kali pengiriman

Not valid for any correction: for live animal this permits is only valid if the transport conditions confrom to the guideline for transport of live animal or IATA regulation, and valid for one shipment only

CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FLORA AND FAUNA		KEMENTERIAN KELAUTAN DAN PERIKANAN DIREKTORAT JENDERAL PENGELOLAAN RUANG LAUT *MINISTRY OF MARINE AFFAIRS AND FISHERIES OF THE REPUBLIC OF INDONESIA* *DIRECTORATE GENERAL MARINE SPATIAL MANAGEMENT*

X. Sertifikat ini diterbitkan oleh :
This permit is issued by

Atas Nama Direktur Jenderal Pengelolaan Ruang Laut
For The Director General Marine Spatial Management

Jakarta, 27 September 2021

KEMENTERIAN KELAUTAN DAN PERIKANAN
DIREKTORAT JENDERAL PENGELOLAAN RUANG LAUT
REPUBLIK INDONESIA

Endratno

Cap/*Official Stamp*

Figure S1.4. Export permits for non-CITES-listed specimens 127/LPSPL.2/PRL.430/X/2021 was granted under the authority of the Ministry of Marine Affairs and Fisheries (MMAF), Republic of Indonesia.

KEMENTERIAN KELAUTAN DAN PERIKANAN
DIREKTORAT JENDERAL
PENGELOLAAN RUANG LAUT
LOKA PENGELOLAAN SUMBERDAYA PESISIR DAN LAUT SERANG
JALAN RAYA CARITA KM 4.5 DESA CARINGIN, KECAMATAN LABUAN, KABUPATEN PANDEGLANG, PROVINSI BANTEN, KODE POS 42264
TELEPON (0253) 802626, FAKSIMILE (0253) 802616
LAMAN https://kkp.go.id/djprl/lpsplserang EMAIL: lpsplserang@kkp.go.id

Nomor : 1276/LPSPL.2/PRL.430/X/2021 07 Oktober 2021
Perihal : Rekomendasi

Kepada Yth.
Pimpinan Pusat Riset Perikanan BRSDMKP
Di –
Jakarta

Menindaklanjuti Surat Saudara nomor 1621/BRSDM.3/RC.510/IX/2021 tanggal 29 September 2021 perihal Permohonan Surat Keterangan Pemeriksaan Bahan Baku, maka telah dilakukan pemeriksaan dan identifikasi oleh petugas Loka Pengelolaan Sumberdaya Pesisir dan Laut Serang dengan hasil yang tercantum dalam berita acara nomor BAP.1826/LPSPL.2/PRL.430/X/2021 tanggal 07 Oktober 2021, bahwa produk sebagai berikut:

No	Jenis Produk	Banyak	Berat	Keterangan
1.	Sampel Penelitian Hiu dan Pari (Sirip)	1 tabung	0,01 kg	*Callorhinchus callorhinschus*
2.	Sampel Penelitian Hiu dan Pari (Daging)	5 tabung	0,05 kg	*Aetomylaeus nichofii*
3.	Sampel Penelitian Hiu dan Pari (Daging)	6 tabung	0,06 kg	*Brevitrygon imbricata*
4.	Sampel Penelitian Hiu dan Pari (Daging)	13 tabung	0,13 kg	*Gymnura zonura*
5.	Sampel Penelitian Hiu dan Pari (Daging)	2 tabung	0,02 kg	*Himantura uarnak*
6.	Sampel Penelitian Hiu dan Pari (Kulit)	1 tabung	0,01 kg	*Himantura undulata*
7.	Sampel Penelitian Hiu dan Pari (Daging)	2 tabung	0,02 kg	*Himantura undulata*
8.	Sampel Penelitian Hiu dan Pari (Daging)	6 tabung	0,06 kg	*Maculabats gerrardi*
9.	Sampel Penelitian Hiu dan Pari (Daging)	9 tabung	0,09 kg	*Neotrygon orientalis*
10.	Sampel Penelitian Hiu dan Pari (Daging)	5 tabung	0,05 kg	*Pateobatis jenkinsii*
11.	Sampel Penelitian Hiu dan Pari (Daging)	6 tabung	0,06 kg	*Pateobatis uarnacoides*
12.	Sampel Penelitian Hiu dan Pari (Daging)	2 tabung	0,02 kg	*Taeniura lymma*
13	Sampel Penelitian Hiu dan Pari (Cartillage)	2 tabung	0,02 kg	Pari Tidak Teridentifikasi
14.	Sampel Penelitian Hiu dan Pari (Sirip)	1 tabung	0,01 kg	Pari Tidak Teridentifikasi
15.	Sampel Penelitian Hiu dan Pari (Daging)	9 tabung	0,09 kg	Pari Tidak Teridentifikasi

16.	Sampel Penelitian Hiu dan Pari (Sirip)	1 tabung	0,01 kg	*Carcharhinus albimaginatus*
17.	Sampel Penelitian Hiu dan Pari (Sirip)	1 tabung	0,01 kg	*Carcharhinus amblyrhynchoides*
18	Sampel Penelitian Hiu dan Pari (Daging)	3 tabung	0,03 kg	*Carcharhinus amblyrhynchoides*
19.	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Carcharhinus amblyrhynchos*
20.	Sampel Penelitian Hiu dan Pari (Daging)	10 tabung	0,10 kg	*Carcharhinus brevipinna*
21	Sampel Penelitian Hiu dan Pari (Sirip)	3 tabung	0,03 kg	*Carcharhinus leucas*
22.	Sampel Penelitian Hiu dan Pari (Kulit)	1 tabung	0,01 kg	*Carcharhinus leucas*
23	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Carcharhinus leucas*
24.	Sampel Penelitian Hiu dan Pari (Daging)	6 tabung	0,06 kg	*Carcharhinus limbatus*
25.	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Carcharhinus melanopterus*
26.	Sampel Penelitian Hiu dan Pari (Dried fin)	6 tabung	0,06 kg	*Carcharhinus obscurus*
27.	Sampel Penelitian Hiu dan Pari (Dried fin)	4 tabung	0,04 kg	*Carcharhinus plumbeus*
28.	Sampel Penelitian Hiu dan Pari (Daging)	5 tabung	0,05 kg	*Carcharhinus sealei*
29.	Sampel Penelitian Hiu dan Pari (Daging)	33 tabung	0,33 kg	*Carcharhinus sorrah*
30	Sampel Penelitian Hiu dan Pari (Sirip)	2 tabung	0,02 kg	*Carcharhinus sp.*
31.	Sampel Penelitian Hiu dan Pari (Daging)	2 tabung	0,02 kg	*Carcharhinus tjutjot*
32.	Sampel Penelitian Hiu dan Pari (Daging)	2 tabung	0,02 kg	*Carcharhinus hasseltii*
33.	Sampel Penelitian Hiu dan Pari (Daging)	2 tabung	0,02 kg	*Carcharhinus indicum*
34.	Sampel Penelitian Hiu dan Pari (Daging)	6 tabung	0,06 kg	*Chiloscyllium punctatum*
35.	Sampel Penelitian Hiu dan Pari (Cartillage)	1 tabung	0,01 kg	*Eusphyrna blochii*
36.	Sampel Penelitian Hiu dan Pari (Cartillage)	1 tabung	0,01 kg	*Galeocerdo cuvier*

37.	Sampel Penelitian Hiu dan Pari (Sirip)	10 tabung	0,10 kg	*Galeocerdo cuvier*
38.	Sampel Penelitian Hiu dan Pari (Kulit)	1 tabung	0,01 kg	*Galeocerdo cuvier*
39.	Sampel Penelitian Hiu dan Pari (Gigi)	1 tabung	0,01 kg	*Galeocerdo cuvier*
40.	Sampel Penelitian Hiu dan Pari (Daging)	3 tabung	0,03 kg	*Galeocerdo cuvier*
41.	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Gymnura zonura*
42.	Sampel Penelitian Hiu dan Pari (Daging)	3 tabung	0,03 kg	*Hemipristis elongata*
43.	Sampel Penelitian Hiu dan Pari (Cartillage)	1 tabung	0,01 kg	*Mustelus schmitti*
44.	Sampel Penelitian Hiu dan Pari (Daging)	3 tabung	0,03 kg	*Mustelus widodoi*
45.	Sampel Penelitian Hiu dan Pari (Cartillage)	1 tabung	0,01 kg	*Prionace glauca*
46.	Sampel Penelitian Hiu dan Pari (Sirip)	4 tabung	0,04 kg	*Prionace glauca*
47.	Sampel Penelitian Hiu dan Pari (Daging)	8 tabung	0,08 kg	*Prionace glauca*
48.	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Pseudocarcharias kamoharai*
49.	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Rhizoprionodon acutus*
50.	Sampel Penelitian Hiu dan Pari (Daging)	1 tabung	0,01 kg	*Squalus montalbani*
51.	Sampel Penelitian Hiu dan Pari (Sirip)	1 tabung	0,01 kg	*Stegostoma fasciatum*
52.	Sampel Penelitian Hiu dan Pari (Kulit)	4 tabung	0,04 kg	*Stegostoma fasciatum*
53.	Sampel Penelitian Hiu dan Pari (Daging)	3 tabung	0,03 kg	*Stegostoma fasciatum*
54.	Sampel Penelitian Hiu dan Pari (Sirip)	1 tabung	0,01 kg	*Triaenodon obesus*
55.	Sampel Penelitian Hiu dan Pari (Cartillage)	8 tabung	0,08 kg	Hiu Tidak Teridentifikasi
56.	Sampel Penelitian Hiu dan Pari (Sirip)	14 tabung	0,14 kg	Tidak Teridentifikasi
57.	Sampel Penelitian Hiu dan Pari (Kulit)	4 tabung	0,04 kg	Tidak Teridentifikasi

KEMENTERIAN KELAUTAN DAN PERIKANAN
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TELEPON (0253) 802626, FAKSIMILE (0253) 802616
LAMAN https://kkp.go.id/djprl/lpsplserang EMAIL: lpsplserang@kkp.go.id

58.	Sampel Penelitian Hiu dan Pari (Daging)	64 tabung	0,64 kg	Tidak Teridentifikasi
59.	Sampel Penelitian Hiu dan Pari (Oil)	7 tabung	0,07 kg	Tidak Teridentifikasi
60.	Sampel Penelitian Hiu dan Pari	81 tabung	0,81 kg	Tidak Teridentifikasi

adalah tidak termasuk jenis dilindungi Peraturan Perundangan, tidak termasuk jenis dalam daftar Appendiks CITES, dan tidak termasuk jenis yang dilarang ke luar Wilayah Negara Republik Indonesia sehingga dapat direkomendasikan perizinan peredarannya untuk proses lebih lanjut sesuai dengan ketentuan yang berlaku. Rekomendasi ini berlaku sampai tanggal 20 Oktober 2021 untuk sekali kirim.

Demikian kami sampaikan, atas perhatian dan kerjasamanya diucapkan terima kasih.

Kepala Loka PSPL Serang

KEMENTERIAN KELAUTAN DAN PERIKANAN DIREKTORAT JENDERAL LOKA PENGELOLAAN SUMBER DAYA PESISIR DAN LAUT SERANG - BANTEN REPUBLIK INDONESIA

Syarif Iwan Taruna Alkadrie, S.T., M.Si

Tembusan :
1. Direktur Jenderal Pengelolaan Ruang Laut
2. Direktur Konservasi dan Keanekaragaman Hayati Laut
3. Kepala BBKIPM Jakarta I Bandara Soekarno-Hatta
4. Kepala BKIPM Kelas 1 Jakarta II Pelabuhan Tanjung Priok
5. Kepala Pangkalan PSDKP Jakarta

BAP.1826.07102021
BAP.1826.07102021

Figure S1.5. Import permit no. 609191/01-42 from the Animal and Plant Health Agency (APHA), United Kingdom.

563344

ORIGINAL

1. Exporter / Re-exporter
PUSAT RISET PERIKANAN
BRSDM KKP - KOTA ADM
JAKARTA UTARA
INDONESIA

PERMIT/CERTIFICATE
☒ IMPORT
☐ EXPORT
☐ RE-EXPORT
☐ OTHER:

No. 609191/01

2. Last day of validity: 27/03/22

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

CITES — Convention on International Trade in Endangered Species Of Wild Fauna and Flora

4. Country of (re-)export: INDONESIA

5. Country of import: UNITED KINGDOM

6. Location at which live specimens of Annex A species will be kept

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero two (0.02) kilograms of Palagic thresher fin samples contained in two vials.

9. Net mass (kg): 0.02 Kg

10. Quantity

11. CITES Appendix: II

12. GB Annex: B

13. Source: W

14. Purpose: S

15. Country of origin: Indonesia

16. Permit No: 00135SAJILNPRLIX2021

17. Date of issue: 27/09/21

18. Country of last re-export

19. Certificate No

20. Date of issue

21. Scientific name of species: Alopias pelagicus

22. Common name of species: Palagic thresher

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)
From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:
Emily Penry
Head of International Trade

Name of issuing official: Matthew Gibbins

Place and date of issue: Bristol. 23 November 2021

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival

Customs Document
Type
Number
Date

Signature and official stamp

1

563345

ORIGINAL

1

1. Exporter / Re-exporter
PUSAT RISET PERIKANAN
BRSDM KKP - KOTA ADM
JAKARTA UTARA
INDONESIA

PERMIT/CERTIFICATE
☒ IMPORT
☐ EXPORT
☐ RE-EXPORT
☐ OTHER:

No. **609191/02**

2. Last day of validity: **27/03/22**

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

CITES — **Convention on International Trade in Endangered Species Of Wild Fauna and Flora**

4. Country of (re)-export: **INDONESIA**

5. Country of import: **UNITED KINGDOM**

6. Location at which live specimens of Annex A species will be kept

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Palagic thresher meat samples contained in one vial.

9. Net mass (kg)	10. Quantity		
0.01 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S

15. Country of origin: **Indonesia**

16. Permit No: **00135SAJILNPRLIX2021**
17. Date of issue: **27/09/21**

18. Country of last re-export

19. Certificate No
20. Date of issue

21. Scientific name of species: **Alopias pelagicus**

22. Common name of species: **Palagic thresher**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)
From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.
Signature and official stamp:
Emily Penry
Head of International Trade
Name of issuing official: **Matthew Gibbins**
Place and date of issue: **Bristol. 23 November 2021**

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563346

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. 609191/03 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM	
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports	
8. Description of specimens (including marks, sex/date of birth for live animals) SPE Zero point zero one (0.01) kilograms of Alopias spp fin samples contained in one vial.	9. Net mass (kg): 0.01 Kg 11. CITES Appendix: II 12. GB Annex: B 15. Country of origin: Indonesia 16. Permit No: 00135SAJILNPRLIX2021 18. Country of last re-export 19. Certificate No	10. Quantity 13. Source: W 14. Purpose: S 17. Date of issue: 27/09/21 20. Date of issue

21. Scientific name of species

Alopias spp.

22. Common name of species

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins Place and date of issue: Bristol. 23 November 2021
26. Bill of Lading/Air Waybill No:	
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

1

ORIGINAL

1

563347

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/04** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero one (0.01) kilograms of Alopias spp cartilage/bone samples contained in one vial.**	9. Net mass (kg) **0.01 Kg** — 10. Quantity 11. CITES Appendix **II** — 12. GB Annex **B** — 13. Source **W** — 14. Purpose **S** 15. Country of origin **Indonesia** 16. Permit No **00135SAJILNPRLIX2021** — 17. Date of issue **27/09/21** 18. Country of last re-export 19. Certificate No — 20. Date of issue

21. Scientific name of species

Alopias spp.

22. Common name of species

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival

Customs Document Type

Number

Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563348

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/05** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero three (0.03) kilograms of Bigeye thresher fin samples contained in three vials.**	9. Net mass (kg): **0.03 Kg** / 10. Quantity: 11. CITES Appendix: **II** / 12. GB Annex: **B** / 13. Source: **W** / 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** / 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: / 20. Date of issue:

21. Scientific name of species: **Alopias superciliosus**

22. Common name of species: **Bigeye thresher**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563349

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. 609191/06 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export INDONESIA 5. Country of import UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports
8. Description of specimens (including marks, sex/date of birth for live animals) SPE Zero point zero one (0.01) kilograms of Bigeye thresher skin samples contained in one vial.	9. Net mass (kg): 0.01 Kg 10. Quantity: 11. CITES Appendix: II 12. GB Annex: B 13. Source: W 14. Purpose: S 15. Country of origin: Indonesia 16. Permit No: 00135SAJILNPRLIX2021 17. Date of issue: 27/09/21 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species

Alopias superciliosus

22. Common name of species

Bigeye thresher

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins
26. Bill of Lading/Air Waybill No:	Place and date of issue: Bristol. 23 November 2021
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

563350

ORIGINAL

1

1. Exporter / Re-exporter
PUSAT RISET PERIKANAN
BRSDM KKP - KOTA ADM
JAKARTA UTARA
INDONESIA

PERMIT/CERTIFICATE
☒ IMPORT
☐ EXPORT
☐ RE-EXPORT
☐ OTHER:

No. 609191/07

2. Last day of validity: 27/03/22

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

CITES — Convention on International Trade in Endangered Species Of Wild Fauna and Flora

4. Country of (re)-export: INDONESIA

5. Country of import: UNITED KINGDOM

6. Location at which live specimens of Annex A species will be kept

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Knifetooth Sawfish fin samples contained in one vial.

9. Net mass (kg): 0.01 Kg

10. Quantity:

11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
I	A	W	S

15. Country of origin: Indonesia

16. Permit No: 00135SAJILNPRLIX2021

17. Date of issue: 27/09/21

18. Country of last re-export:

19. Certificate No:

20. Date of issue:

21. Scientific name of species: Anoxypristis cuspidata

22. Common name of species: Knifetooth Sawfish

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: Matthew Gibbins

Place and date of issue: Bristol. 23 November 2021

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival

Customs Document Type

Number

Date

Signature and official stamp

FED 0610 (March 19) Revised

1

563351

ORIGINAL

1

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. 609191/08 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports
8. Description of specimens (including marks, sex/date of birth for live animals) SPE Zero point zero three (0.03) kilograms of Knifetooth Sawfish rostrum samples contained in three vials.	9. Net mass (kg): 0.03 Kg 10. Quantity: 11. CITES Appendix: I 12. GB Annex: A 13. Source: W 14. Purpose: S 15. Country of origin: Indonesia 16. Permit No: 00135SAJILNPRLIX2021 17. Date of issue: 27/09/21 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species: **Anoxypristis cuspidata**

22. Common name of species: **Knifetooth Sawfish**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins
26. Bill of Lading/Air Waybill No:	Place and date of issue: Bristol. 23 November 2021
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

563352

ORIGINAL 1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/09** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	**Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**	
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**	

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero six (0.06) kilograms of Silky shark fin samples contained in six vials.

9. Net mass (kg)	10. Quantity		
0.06 Kg			
11. CITES Appendix	**12. GB Annex**	**13. Source**	**14. Purpose**
II	**B**	**W**	**S**

15. Country of origin **Indonesia**

16. Permit No	17. Date of issue
00135SAJILNPRLIX2021	**27/09/21**

18. Country of last re-export

19. Certificate No	20. Date of issue

21. Scientific name of species
Carcharhinus falciformis

22. Common name of species
Silky shark

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)
From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.
Signature and official stamp:
Emily Penry
Head of International Trade
Name of issuing official: **Matthew Gibbins**

26. Bill of Lading/Air Waybill No:

Place and date of issue: **Bristol.** **23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

FED 0610 (March 19) Revised

1

563353

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/10** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point three four (0.34) kilograms of Silky shark meat samples contained in thirty four vials.**	9. Net mass (kg): **0.34 Kg** — 10. Quantity: 11. CITES Appendix: **II** — 12. GB Annex: **B** — 13. Source: **W** — 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** — 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: — 20. Date of issue:

21. Scientific name of species
Carcharhinus falciformis

22. Common name of species
Silky shark

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563354

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/11** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero five (0.05) kilograms of Carcharhinus longimanus fin samples contained in five vials.**	9. Net mass (kg): **0.05 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species **Carcharhinus longimanus**	
22. Common name of species	

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563355

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. 609191/12 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export INDONESIA 5. Country of import UNITED KINGDOM	
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports	

8. Description of specimens (including marks, sex/date of birth for live animals)	9. Net mass (kg)		10. Quantity	
SPE Zero point zero one (0.01) kilograms of Glaucostegus spp skin samples contained in one vial.	0.01 Kg			
	11. CITES Appendix: II	12. GB Annex: B	13. Source: W	14. Purpose: S
	15. Country of origin: Indonesia			
	16. Permit No: 00135SAJILNPRLIX2021		17. Date of issue: 27/09/21	
	18. Country of last re-export			
	19. Certificate No		20. Date of issue	

21. Scientific name of species

Glaucostegus spp.

22. Common name of species

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins
26. Bill of Lading/Air Waybill No:	Place and date of issue: Bristol. 23 November 2021
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

FED 0610 (March 19) Revised

1

ORIGINAL

1

563356

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/13** 2. Last day of validity: **27/03/22**

3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	**CITES** **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**

8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero three (0.03) kilograms of Glaucostegus spp fin samples contained in three vials.**	9. Net mass (kg) **0.03 Kg**		10. Quantity	
	11. CITES Appendix **II**	12. GB Annex **B**	13. Source **W**	14. Purpose **S**
	15. Country of origin **Indonesia**			
	16. Permit No **00135SAJILNPRLIX2021**		17. Date of issue **27/09/21**	
	18. Country of last re-export			
	19. Certificate No		20. Date of issue	

21. Scientific name of species

Glaucostegus spp.

22. Common name of species

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563357

1. Exporter / Re-exporter	PERMIT/CERTIFICATE	No. 609191/14
PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	2. Last day of validity: 27/03/22

3. Importer	Convention on International Trade in Endangered Species Of Wild Fauna and Flora
UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero seven (0.07) kilograms of Clubnose guitarfish meat samples contained in seven vials.

9. Net mass (kg)		10. Quantity	
0.07 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S
15. Country of origin: Indonesia			
16. Permit No		17. Date of issue	
00135SAJILNPRLIX2021		27/09/21	
18. Country of last re-export			
19. Certificate No		20. Date of issue	

21. Scientific name of species
Glaucostegus thouin

22. Common name of species
Clubnose guitarfish

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

26. Bill of Lading/Air Waybill No:

Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

1

ORIGINAL

1

563358

1. Exporter / Re-exporter	PERMIT/CERTIFICATE	No. 609191/15
PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	2. Last day of validity: 27/03/22

3. Importer	Convention on International Trade in Endangered Species Of Wild Fauna and Flora
UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	4. Country of (re)-export INDONESIA 5. Country of import UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Common shovelnose ray meat samples contained in one vial.

9. Net mass (kg)		10. Quantity	
0.01 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S
15. Country of origin Indonesia			
16. Permit No		17. Date of issue	
00135SAJILNPRLIX2021		27/09/21	
18. Country of last re-export			
19. Certificate No		20. Date of issue	

21. Scientific name of species
Glaucostegus typus

22. Common name of species
Common shovelnose ray

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.
Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: Matthew Gibbins

26. Bill of Lading/Air Waybill No:

Place and date of issue: Bristol. 23 November 2021

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

Signature and official stamp

FED 0610 (March 19) Revised

1

563359

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/16** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero four (0.04) kilograms of Shortfin mako fin samples contained in four vials.**	9. Net mass (kg) **0.04 Kg** 10. Quantity 11. CITES Appendix **II** 12. GB Annex **B** 13. Source **W** 14. Purpose **S** 15. Country of origin **Indonesia** 16. Permit No **00135SAJILNPRLIX2021** 17. Date of issue **27/09/21** 18. Country of last re-export 19. Certificate No 20. Date of issue
21. Scientific name of species **Isurus oxyrinchus**	
22. Common name of species **Shortfin mako**	

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol.** **23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563360

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/17** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	**CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**	
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**	

8. Description of specimens (including marks, sex/date of birth for live animals)	9. Net mass (kg)		10. Quantity	
SPE **Zero point zero one (0.01) kilograms of Shortfin mako cartilage/bone samples contained in one vial.**	**0.01 Kg**			
	11. CITES Appendix: **II**	12. GB Annex: **B**	13. Source: **W**	14. Purpose: **S**
	15. Country of origin: **Indonesia**			
	16. Permit No: **00135SAJILNPRLIX2021**		17. Date of issue: **27/09/21**	
	18. Country of last re-export			
	19. Certificate No		20. Date of issue	

21. Scientific name of species
Isurus oxyrinchus

22. Common name of species
Shortfin mako

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563361

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/18** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	**Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero five (0.05) kilograms of Longfin mako fin samples contained in five vials.**	9. Net mass (kg): **0.05 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species: **Isurus paucus**

22. Common name of species: **Longfin mako**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol.** **23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

1

563362

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/19** 2. Last day of validity: **27/03/22**

3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Mako shark fin samples contained in one vial.

9. Net mass (kg)		10. Quantity	
0.01 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	**B**	**W**	**S**

15. Country of origin **Indonesia**

16. Permit No	17. Date of issue
00135SAJILNPRLIX2021	**27/09/21**

18. Country of last re-export

19. Certificate No	20. Date of issue

21. Scientific name of species
Isurus spp.

22. Common name of species
Mako sharks

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES.Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)
From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

Place and date of issue: **Bristol. 23 November 2021**

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563363

1. Exporter / Re-exporter	PERMIT/CERTIFICATE	
PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/20** 2. Last day of validity: 27/03/22

3. Importer	
UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES — **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Mako shark meat samples contained in one vial.

9. Net mass (kg)	10. Quantity		
0.01 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S

15. Country of origin: Indonesia

16. Permit No	17. Date of issue
00135SAJILNPRLIX2021	27/09/21

18. Country of last re-export

19. Certificate No	20. Date of issue

21. Scientific name of species: **Isurus spp.**

22. Common name of species: **Mako sharks**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

Place and date of issue: **Bristol. 23 November 2021**

26. Bill of Lading/Air Waybill No:

27. For customs use only

Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

563364

ORIGINAL

1

1. Exporter / Re-exporter	PERMIT/CERTIFICATE	
PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/21** 2. Last day of validity: 27/03/22

3. Importer	
UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	**Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero four (0.04) kilograms of Porbeagle shark fin samples contained in four vials.

9. Net mass (kg)	10. Quantity		
0.04 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S
15. Country of origin: Indonesia			
16. Permit No: 00135SAJILNPRLIX2021		17. Date of issue: 27/09/21	
18. Country of last re-export			
19. Certificate No		20. Date of issue	

21. Scientific name of species
Lamna nasus

22. Common name of species
Porbeagle shark

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

26. Bill of Lading/Air Waybill No:

Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

FED 0810 (March 19) Revised

1

ORIGINAL

1

563365

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:
No. **609191/22**	2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero one (0.01) kilograms of Manta birostris gill samples contained in one vial.**	9. Net mass (kg): **0.01 Kg** — 10. Quantity: 11. CITES Appendix: **II** — 12. GB Annex: **B** — 13. Source: **W** — 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** — 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: — 20. Date of issue:

21. Scientific name of species
Manta birostris

22. Common name of species

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)
From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563366

1. Exporter / Re-exporter
PUSAT RISET PERIKANAN
BRSDM KKP - KOTA ADM
JAKARTA UTARA
INDONESIA

PERMIT/CERTIFICATE
☒ IMPORT
☐ EXPORT
☐ RE-EXPORT
☐ OTHER:

No. **609191/23**

2. Last day of validity:
27/03/22

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

Convention on International Trade in Endangered Species Of Wild Fauna and Flora

4. Country of (re)-export
INDONESIA

5. Country of import
UNITED KINGDOM

6. Location at which live specimens of Annex A species will be kept

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Manta spp gill samples contained in one vial.

9. Net mass (kg): **0.01 Kg**

10. Quantity:

11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S

15. Country of origin **Indonesia**

16. Permit No **00135SAJILNPRLIX2021**

17. Date of issue **27/09/21**

18. Country of last re-export

19. Certificate No

20. Date of issue

21. Scientific name of species
Manta spp.

22. Common name of species

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)
From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

Place and date of issue: **Bristol. 23 November 2021**

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

Signature and official stamp

1

ORIGINAL

1

563367

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/24** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	**Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero four (0.04) kilograms of Devil ray gill samples contained in four vials.**	9. Net mass (kg): **0.04 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species **Mobula spp.**	
22. Common name of species **Devil ray**	

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563368

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/25** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero one (0.01) kilograms of Common Sawfish fin samples contained in one vial.**	9. Net mass (kg): **0.01 Kg** 10. Quantity: 11. CITES Appendix: **I** 12. GB Annex: **A** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species: **Pristis pristis**

22. Common name of species: **Common Sawfish**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

FED 0610 (March 19) Revised

1

ORIGINAL

1

563369

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/26** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero four (0.04) kilograms of Rhina ancylostoma fin samples contained in four vials.**	9. Net mass (kg): **0.04 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species **Rhina ancylostoma**	
22. Common name of species	

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins.**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

FED 0610 (March 19) Revised

1

ORIGINAL

1

563370

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/27** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES — **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero two (0.02) kilograms of Rhina ancylostoma meat samples contained in two vials.**	9. Net mass (kg): **0.02 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species

Rhina ancylostoma

22. Common name of species

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

1

563371

ORIGINAL

1

1. Exporter / Re-exporter	PERMIT/CERTIFICATE	No. 609191/28
PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	2. Last day of validity: 27/03/22

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

CITES — Convention on International Trade in Endangered Species Of Wild Fauna and Flora

4. Country of (re-)export: INDONESIA

5. Country of import: UNITED KINGDOM

6. Location at which live specimens of Annex A species will be kept:

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero one (0.01) kilograms of Rhina ancylostoma skin samples contained in one vial.

9. Net mass (kg)	10. Quantity		
0.01 Kg			
11. CITES Appendix	**12. GB Annex**	**13. Source**	**14. Purpose**
II	B	W	S

15. Country of origin: Indonesia

16. Permit No	17. Date of issue
00135SAJILNPRLIX2021	27/09/21

18. Country of last re-export:

19. Certificate No	20. Date of issue

21. Scientific name of species: Rhina ancylostoma

22. Common name of species:

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

Place and date of issue: **Bristol. 23 November 2021**

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

1

563372

ORIGINAL

1

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. 609191/29 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports
8. Description of specimens (including marks, sex/date of birth for live animals) SPE Zero point one seven (0.17) kilograms of Bottlenose wedgefish meat samples contained in seventeen vials.	9. Net mass (kg): 0.17 Kg 10. Quantity: 11. CITES Appendix: II 12. GB Annex: B 13. Source: W 14. Purpose: S 15. Country of origin: Indonesia 16. Permit No: 00135SAJILNPRLIX2021 17. Date of issue: 27/09/21 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species

Rhynchobatus australiae

22. Common name of species

Bottlenose wedgefish

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins
26. Bill of Lading/Air Waybill No:	Place and date of issue: Bristol. 23 November 2021

27. For customs use only

Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563373

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/30** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	**Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**	
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**	

8. Description of specimens (including marks, sex/date of birth for live animals)	9. Net mass (kg)	10. Quantity		
SPE **Zero point zero one (0.01) kilograms of Bottlenose wedgefish fin samples contained in one vial.**	**0.01 Kg**			
	11. CITES Appendix: **II**	12. GB Annex: **B**	13. Source: **W**	14. Purpose: **S**
	15. Country of origin: **Indonesia**			
	16. Permit No: **00135SAJILNPRLIX2021**	17. Date of issue: **27/09/21**		
	18. Country of last re-export			
	19. Certificate No	20. Date of issue		

21. Scientific name of species: **Rhynchobatus australiae**

22. Common name of species: **Bottlenose wedgefish**

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

ORIGINAL

1

563376

1. Exporter / Re-exporter
PUSAT RISET PERIKANAN
BRSDM KKP - KOTA ADM
JAKARTA UTARA
INDONESIA

PERMIT/CERTIFICATE
☒ IMPORT
☐ EXPORT
☐ RE-EXPORT
☐ OTHER:

No. **609191/31**

2. Last day of validity:
27/03/22

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora**

4. Country of (re)-export
INDONESIA

5. Country of import
UNITED KINGDOM

6. Location at which live specimens of Annex A species will be kept

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero six (0.06) kilograms of Rhynchobatus laevis meat samples contained in six vials.

9. Net mass (kg)		10. Quantity	
0.06 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	**B**	**W**	**S**

15. Country of origin **Indonesia**

16. Permit No	17. Date of issue
00135SAJILNPRLIX2021	**27/09/21**

18. Country of last re-export

19. Certificate No	20. Date of issue

21. Scientific name of species
Rhynchobatus laevis

22. Common name of species

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

26. Bill of Lading/Air Waybill No:

Place and date of issue: **Bristol.** **23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

Signature and official stamp

FED 0610 (March 19) Revised

1

563377

ORIGINAL

1

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. 609191/32 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports
8. Description of specimens (including marks, sex/date of birth for live animals) SPE Zero point zero three (0.03) kilograms of Rhynchobatus spp meat samples contained in three vials.	9. Net mass (kg): 0.03 Kg 10. Quantity: 11. CITES Appendix: II 12. GB Annex: B 13. Source: W 14. Purpose: S 15. Country of origin: Indonesia 16. Permit No: 00135SAJILNPRLIX2021 17. Date of issue: 27/09/21 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species: Rhynchobatus spp.	
22. Common name of species	

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins
26. Bill of Lading/Air Waybill No:	Place and date of issue: Bristol. 23 November 2021
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

FED 0610 (March 19) Revised

ORIGINAL 1

563378

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/33** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero four (0.04) kilograms of Rhynchobatus spp fin samples contained in four vials.**	9. Net mass (kg): **0.04 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species
Rhynchobatus spp.

22. Common name of species

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

FED 0610 (March 19) Revised

1

563379

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/34** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES — **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero one (0.01) kilograms of Rhynchobatus spp cartilage/bone samples contained in one vial.**	9. Net mass (kg): **0.01 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species **Rhynchobatus spp.**	
22. Common name of species	

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

ORIGINAL

563380

1. Exporter / Re-exporter PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. 609191/35 2. Last day of validity: 27/03/22
3. Importer UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT	CITES — Convention on International Trade in Endangered Species Of Wild Fauna and Flora 4. Country of (re)-export: INDONESIA 5. Country of import: UNITED KINGDOM
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports
8. Description of specimens (including marks, sex/date of birth for live animals) SPE Zero point one six (0.16) kilograms of Rhynchobatus springeri meat samples contained in sixteen vials.	9. Net mass (kg): 0.16 Kg 10. Quantity: 11. CITES Appendix: II 12. GB Annex: B 13. Source: W 14. Purpose: S 15. Country of origin: Indonesia 16. Permit No: 00135SAJILNPRLIX2021 17. Date of issue: 27/09/21 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species: Rhynchobatus springeri	
22. Common name of species:	

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: Emily Penry Head of International Trade Name of issuing official: Matthew Gibbins
26. Bill of Lading/Air Waybill No:	Place and date of issue: Bristol. 23 November 2021

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type Number Date

Signature and official stamp

1

ORIGINAL

1

563381

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/36** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	**CITES** **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point one nine (0.19) kilograms of Scalloped hammerhead meat samples contained in nineteen vials.**	9. Net mass (kg): **0.19 Kg** — 10. Quantity: 11. CITES Appendix: **II** — 12. GB Annex: **B** — 13. Source: **W** — 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** — 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: — 20. Date of issue:

21. Scientific name of species: **Sphyrna lewini**

22. Common name of species: **Scalloped hammerhead**

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only — Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

FED 0610 (March 19) Revised

1

563382

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:
	No. **609191/37** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	**Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE Zero point zero two (0.02) kilograms of Scalloped hammerhead fin samples contained in two vials.**	9. Net mass (kg): **0.02 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:
21. Scientific name of species: **Sphyrna lewini**	
22. Common name of species: **Scalloped hammerhead**	

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

1

563383

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN BRSDM KKP - KOTA ADM JAKARTA UTARA INDONESIA**	PERMIT/CERTIFICATE ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER:	No. **609191/38** 2. Last day of validity: **27/03/22**

3. Importer **UNIVERSITY OF SALFORD ANDHIKA PRIMA PRASETYO ROOM 334 PEEL BUILDING THE UNIVERSITY OF SALFORD MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export **INDONESIA** 5. Country of import **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA) UK CITES Management Authority Horizon House Deanery Road Bristol BS1 5AH Tel: +44(0)117 372 3700 Website: www.gov.uk/cites-imports-and-exports**

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero two (0.02) kilograms of Great hammerhead meat samples contained in two vials.

9. Net mass (kg)		10. Quantity	
0.02 Kg			
11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	**B**	**W**	**S**
15. Country of origin **Indonesia**			
16. Permit No		17. Date of issue	
00135SAJILNPRLIX2021		**27/09/21**	
18. Country of last re-export			
19. Certificate No		20. Date of issue	

21. Scientific name of species
Sphyrna mokarran

22. Common name of species
Great hammerhead

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

26. Bill of Lading/Air Waybill No:

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: **Matthew Gibbins**

Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

1

563384

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/39** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES — **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero three (0.03) kilograms of Great hammerhead fin samples contained in three vials.**	9. Net mass (kg): **0.03 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species
Sphyrna mokarran

22. Common name of species
Great hammerhead

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol.** **23 November 2021**
27. For customs use only	Signature and official stamp

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number
		Date

1

563385

ORIGINAL

1

1. Exporter / Re-exporter **PUSAT RISET PERIKANAN** **BRSDM KKP - KOTA ADM** **JAKARTA UTARA** **INDONESIA**	**PERMIT/CERTIFICATE** ☒ IMPORT ☐ EXPORT ☐ RE-EXPORT ☐ OTHER: No. **609191/40** 2. Last day of validity: **27/03/22**
3. Importer **UNIVERSITY OF SALFORD** **ANDHIKA PRIMA PRASETYO** **ROOM 334** **PEEL BUILDING** **THE UNIVERSITY OF SALFORD** **MANCHESTER M5 4WT**	CITES **Convention on International Trade in Endangered Species Of Wild Fauna and Flora** 4. Country of (re)-export: **INDONESIA** 5. Country of import: **UNITED KINGDOM**
6. Location at which live specimens of Annex A species will be kept	7. Issuing Management Authority **Animal and Plant Health Agency (APHA)** **UK CITES Management Authority** **Horizon House** **Deanery Road** **Bristol BS1 5AH** **Tel: +44(0)117 372 3700** **Website: www.gov.uk/cites-imports-and-exports**
8. Description of specimens (including marks, sex/date of birth for live animals) **SPE** **Zero point zero nine (0.09) kilograms of Sphyrna spp meat samples contained in nine vials.**	9. Net mass (kg): **0.09 Kg** 10. Quantity: 11. CITES Appendix: **II** 12. GB Annex: **B** 13. Source: **W** 14. Purpose: **S** 15. Country of origin: **Indonesia** 16. Permit No: **00135SAJILNPRLIX2021** 17. Date of issue: **27/09/21** 18. Country of last re-export: 19. Certificate No: 20. Date of issue:

21. Scientific name of species

Sphyrna spp.

22. Common name of species

23. Special conditions

This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export ☐ has been surrendered to the issuing authority ☐ has to be surrendered to the border customs office of introduction FOREST PROTECTION & NATURE CONSERVATION, MIN OF FORESTRY GEDUNG MANGGALA	25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted. Signature and official stamp: **Emily Penry** **Head of International Trade** Name of issuing official: **Matthew Gibbins**
26. Bill of Lading/Air Waybill No:	Place and date of issue: **Bristol. 23 November 2021**

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival	Customs Document Type
		Number Date

Signature and official stamp

1

563386

ORIGINAL

1

1. Exporter / Re-exporter
PUSAT RISET PERIKANAN
BRSDM KKP - KOTA ADM
JAKARTA UTARA
INDONESIA

PERMIT/CERTIFICATE
☒ IMPORT
☐ EXPORT
☐ RE-EXPORT
☐ OTHER:

No. 609191/41

2. Last day of validity:
27/03/22

3. Importer
UNIVERSITY OF SALFORD
ANDHIKA PRIMA PRASETYO
ROOM 334
PEEL BUILDING
THE UNIVERSITY OF SALFORD
MANCHESTER M5 4WT

Convention on International Trade in Endangered Species Of Wild Fauna and Flora

4. Country of (re)-export
INDONESIA

5. Country of import
UNITED KINGDOM

6. Location at which live specimens of Annex A species will be kept

7. Issuing Management Authority
Animal and Plant Health Agency (APHA)
UK CITES Management Authority
Horizon House
Deanery Road
Bristol BS1 5AH
Tel: +44(0)117 372 3700
Website: www.gov.uk/cites-imports-and-exports

8. Description of specimens (including marks, sex/date of birth for live animals)
SPE
Zero point zero eight (0.08) kilograms of Sphyrna spp fin samples contained in eight vials.

9. Net mass (kg)
0.08 Kg

10. Quantity

11. CITES Appendix	12. GB Annex	13. Source	14. Purpose
II	B	W	S

15. Country of origin Indonesia

16. Permit No
00135SAJILNPRLIX2021

17. Date of issue
27/09/21

18. Country of last re-export

19. Certificate No

20. Date of issue

21. Scientific name of species
Sphyrna spp.

22. Common name of species

23. Special conditions
This permit/certificate is only valid if live animals are transported in compliance with the CITES Guidelines for the transport and Preparation for Shipment of Live Wild Animals or, in the case of air transport, the Live Animals Regulations published by the International Air Transport Association (IATA)

From 1 January 2021 imports and exports of CITES specimens to and from the UK may only take place at the designated UK ports listed at: https://www.gov.uk/guidance/trading-cites-listed-species-through-uk-ports-and-airports-after-brexit

24. The (re-)export documentation from the country of (re-)export
☐ has been surrendered to the issuing authority
☐ has to be surrendered to the border customs office of introduction

FOREST PROTECTION & NATURE
CONSERVATION, MIN OF FORESTRY
GEDUNG MANGGALA

25. The ☒ importation ☐ exportation ☐ re-exportation of the goods described above is hereby permitted.

Signature and official stamp:

Emily Penry
Head of International Trade

Name of issuing official: Matthew Gibbins

Place and date of issue: Bristol. 23 November 2021

26. Bill of Lading/Air Waybill No:

27. For customs use only

Quantity/net mass (kg) actually imported or (re-) exported	Number of animals dead on arrival

Customs Document Type

Number

Date

Signature and official stamp

FED 0610 (March 19) Revised

Instructions and explanations

1. Full name and address of the actual (re-)exporter, not of an agent. In the case of a personal ownership certificate or of a musical instrument certificate, the full name and address of the legal owner. In the case of a musical instrument certificate, if the applicant is different from the legal owner, the full name and address of both the owner and of the applicant should be included in the form and a copy of a loan agreement between owner and applicant should be provided to the relevant permit issuing authority.

2. The period of validity of an export permit or re-export certificate shall not exceed six months and of an import permit 12 months. The period of validity of a personal ownership certificate and of a musical instrument certificate shall not exceed three years. After its last day of validity, this document is void and the original and all copies must be returned by the holder to the issuing management authority without undue delay. An import permit is not valid where the corresponding CITES document from the (re-)exporting country was used for (re-)export after its last day of validity or if the date of introduction into Great Britain is more than six months from its date of issue.

3. Full name and address of the actual importer, not of an agent. To be left blank in the case of a personal ownership certificate or of a musical instrument certificate.

5. To be left blank in the case of a personal ownership certificate or of a musical instrument certificate.

6. For live specimens of Annex A species other than captive bred or artificially propagated specimens, the issuing authority may prescribe the location at which they are to be kept by including details thereof in this box. Any movement, except for urgent veterinary treatment and provided the specimens are returned directly to their authorized location, then requires prior authorization from the competent management authority.

8. Description must be as precise as possible and include a three-letter code in accordance with Annex VII to Regulation (EC) No. 865/2006 laying down detailed rules concerning the implementation of Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora by regulating trade therein. In the case of a musical instrument certificate, the description of the instrument should allow the competent authority to verify that the certificate corresponds to the specimen being imported or exported, and the description should include elements such as the manufacturer's name, the serial number or other means of identification such as photographs.

9/10 Use the units of quantity and/or net mass in accordance with those contained in Annex VII to Regulation (EC) No 865/2006.

11. Enter the number of the CITES appendix (I, II or III) in which the species is listed at the date of issue of the permit/certificate.

12. Enter the letter of the Annex to Regulation (EC) No 338/97 (A,B or C) in which the species is listed at the date of issue of the permit/certificate.

13. Use one of the following codes to indicate the source:

- W Specimens taken from the wild
- R Specimens of animals reared in a controlled environment, taken as eggs or juveniles from the wild where they would otherwise have had a very low probability of surviving to adulthood.
- D Annex A animals bred in captivity for commercial purposes in operations included in the Register of the CITES Secretariat, in accordance with resolution Conf. 12.10 (Rev. CoP15), and Annex A plants artificially propagated for commercial purposes in accordance with Chapter XIII of Regulation (EC) No 865/2006, as well as parts and derivatives thereof.
- A Annex A plants artificially propagated for non-commercial purposes and Annexes B and C plants artificially propagated in accordance with Chapter XIII of Regulation (EC) No 865/2006, as well as parts and derivatives thereof.
- C Animals bred in captivity in accordance with Chapter XIII of Regulation (EC) No 865/2006, as well as parts and derivatives thereof.
- F Animals born in captivity, but for which the criteria of Chapter XIII of Regulation (EC) No 865/2006 are not met, as well as parts and derivatives thereof.
- I Confiscated or seized specimens (1)
- O Pre-convention (1)
- U Source unknown (must be justified)
- X Specimens taken in the marine environment not under the jurisdiction of any State.

(1) To be used only in conjunction with another source code.

14. Use one of the following codes to indicate the purpose for which the specimens are to be (re-)exported/imported:

- B Breeding in captivity or artificial propagation
- E Educational
- G Botanical gardens
- H Hunting trophies
- L Law enforcement/judicial/forensic
- M Medical (including bio-medical research)
- N Reintroduction or introduction into the wild
- P Personal
- Q Travelling exhibitions (sample collection, circus, menagerie, plant exhibition, orchestra or museums exhibition that is used for commercial display for the public)
- S Scientific
- T Commercial
- Z Zoos

15 to 17. The country of origin is the country where the specimens were taken from the wild, born and bred in captivity or artificially propagated. Where this is outside Great Britain, boxes 16 and 17 must contain details of the relevant permit.

18 to 20. The country of last re-export is, in the case of a re-export certificate, the re-exporting third country from which the specimens were imported before being re-exported from Great Britain. In the case of an import permit, it is the re-exporting third country from which the specimens are to be imported. Boxes 19 and 20 must contain details of the relevant re-export certificate.

21. The scientific name must be in accordance with the standard references for nomenclature referred to in Annex VIII to Regulation (EC) No 865/2006.

23 to 25. For official use only.

26. The importer/(re)exporter or his agent must, where appropriate, indicate the number of the bill of lading or air waybill.

27. To be completed by the customs office of introduction into Great Britain or that of (re-)export as appropriate. In the case of introduction, the original (form 1) must be returned to the management authority of the United Kingdom and the copy for the holder (form 2) to the importer. In the case of (re-)export, the copy for return by customs to the issuing authority (form 3) must be returned to the management authority of the United Kingdom and the original (form 1) and the copy for the holder (form 2) to the (re-)exporter.

Supplementary material – Chapter 2

Figure S2.1. Domestic trade network of fin and meat products across Indonesia region within 2014-2018 (ton)

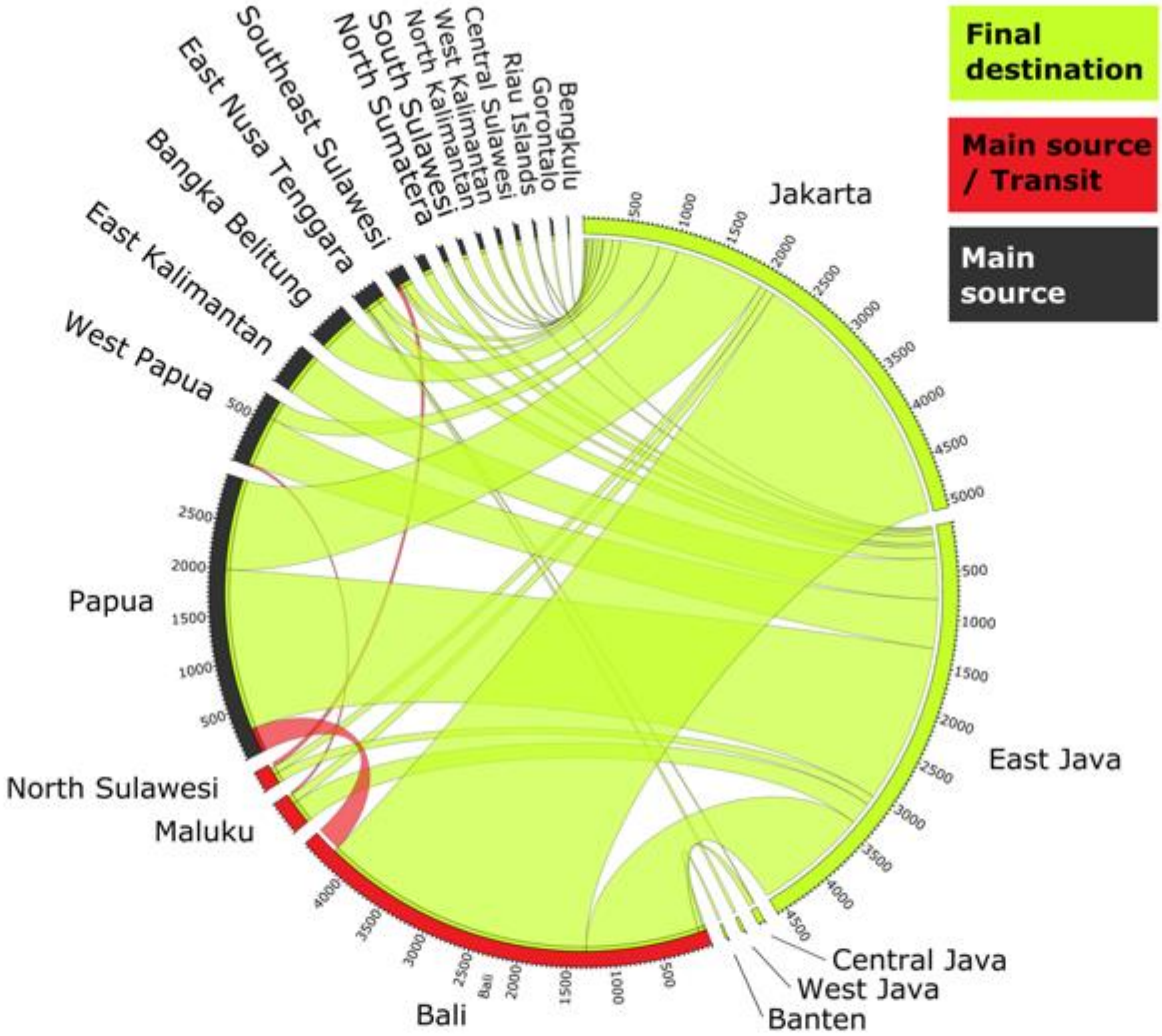


Figure S2.2. Annual volume of reported export and import by/from Indonesia in 2012-2018 for fin products (a) and meat products (b)

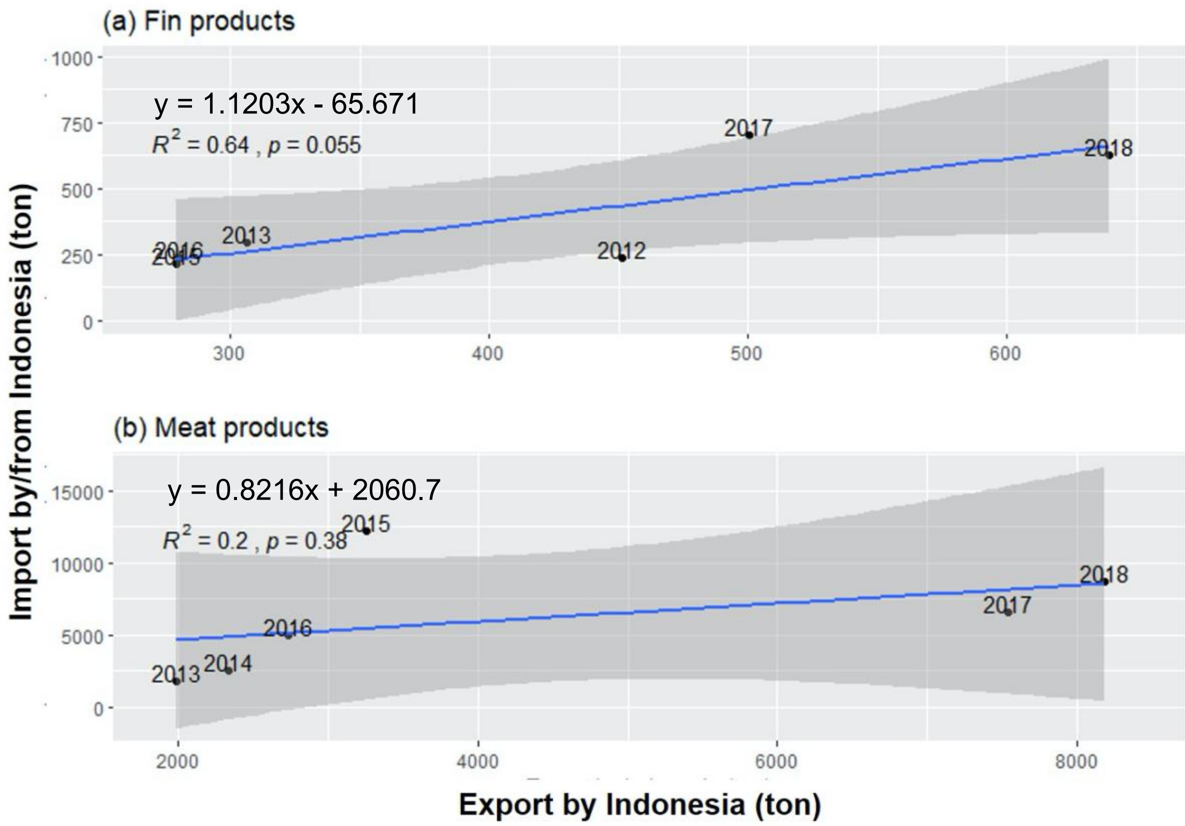


Table S2.1. Shark and ray production and trade data used in this study. Trade data include HS Code and descriptions of shark and ray commodities.

Data source	Information	Designation
Production statistics		
Indonesian Marine and Fisheries in Figure 1975-2016 (MMAF, 2017)	Species, fisheries management area, province, volume	Indonesia classification on sharks and rays
One Data of Indonesian fisheries 2017-2018 (MMAF, 2020)	Species, fisheries management area, province, volume	Indonesia classification on sharks and rays
FAO Global capture production 1950-2018. Accessed via FishstatJ data (FAO, 2020a)	Country, species, volume, value	ISSCAAP group > Sharks, rays, chimaeras
Trade statistics		
FAO Global Fisheries commodities production and trade 1976-2017. Accessed via FishstatJ data (FAO, 2020a)	Flow, source and destination country, commodity, HS code, volume, value	ISSCAAP group > Sharks, rays, chimaeras
Indonesian fish quarantine data 2014-2018. Accessed via online query panels, 2010-2016 (AFQQI-MMAF, 2019)	Flow, source and destination country, commodity, volume, value	Indonesia classification on sharks and rays

Table S2.2. Shark product HS codes used in trade, 2008–2018 (UN Comtrade)

HS Code	Meat	HS Code	Fins
03.02.65	Dogfish & other sharks, fresh/chilled (excl. fillets/other fish meat of 03.04/livers & roes)	03.02.92	Fish; fresh or chilled, shark fins
03.02.81	Fish; fresh or chilled, dogfish and other sharks, excluding fillets, fish meat of 0304, and edible fish offal of subheadings 0302.91 to 0302.99	03.03.92	Fish; frozen, shark fins
03.03.75	Dogfish & oth. sharks, frozen (excl. fillets/oth. fish meat of 03.04/livers & roes)	03.05.71	Fish; edible offal, shark fins
03.03.81	Fish; frozen, dogfish and other sharks, excluding fillets, fish meat of 0304, and edible fish offal of subheadings 0303.91 to 0303.99	1604.18	Fish preparations; shark fins, prepared or preserved, whole or in pieces (but not minced)
03.04.47	Fish fillets; fresh or chilled, dogfish and other sharks		
03.04.56	Fish meat; excluding fillets, whether or not minced; fresh or chilled, dogfish and other sharks		
03.04.88	Fish fillets; frozen, dogfish, other sharks, rays and skates (Rajidae)		
03.04.96	Fish meat, excluding fillets, whether or not minced; frozen, dogfish and other sharks		

Notes: The Harmonized System (HS) product code is a standardized numerical method of classifying traded products. Those six-digit code (except for 160418) structured into 3 section i.e. chapter (product), heading (type of treatment), and subheading (specify the species). First two-digit stands for fish and crustaceans, molluscs and other aquatic invertebrates. While the next two digits refer to the treatment i.e. 01 if for “live”, 02 is for “fresh or chilled”, 03 is for “frozen”, 04 is for “filleted”, and 05 is for “dried, salted, smoked, and pelleted”. Then, after the first four digits used to specify the species. Meanwhile, 1604 stands for “prepared or preserved fish” and the last two-digit refer to sharks. Additionally, this 6 six-digit international code could be added a national classification code to increase clarity.

Supplementary material – Chapter 3

Figure S3.1. A schematic description of the stages of this study which include (a) sample collection and preservation, (b) DNA extraction of tissue samples, (c-e) sample processing using the FASTFISH-ID workflow, (f) visualisation of the RT-PCR outputs and (g and h) species classification using deep learning.

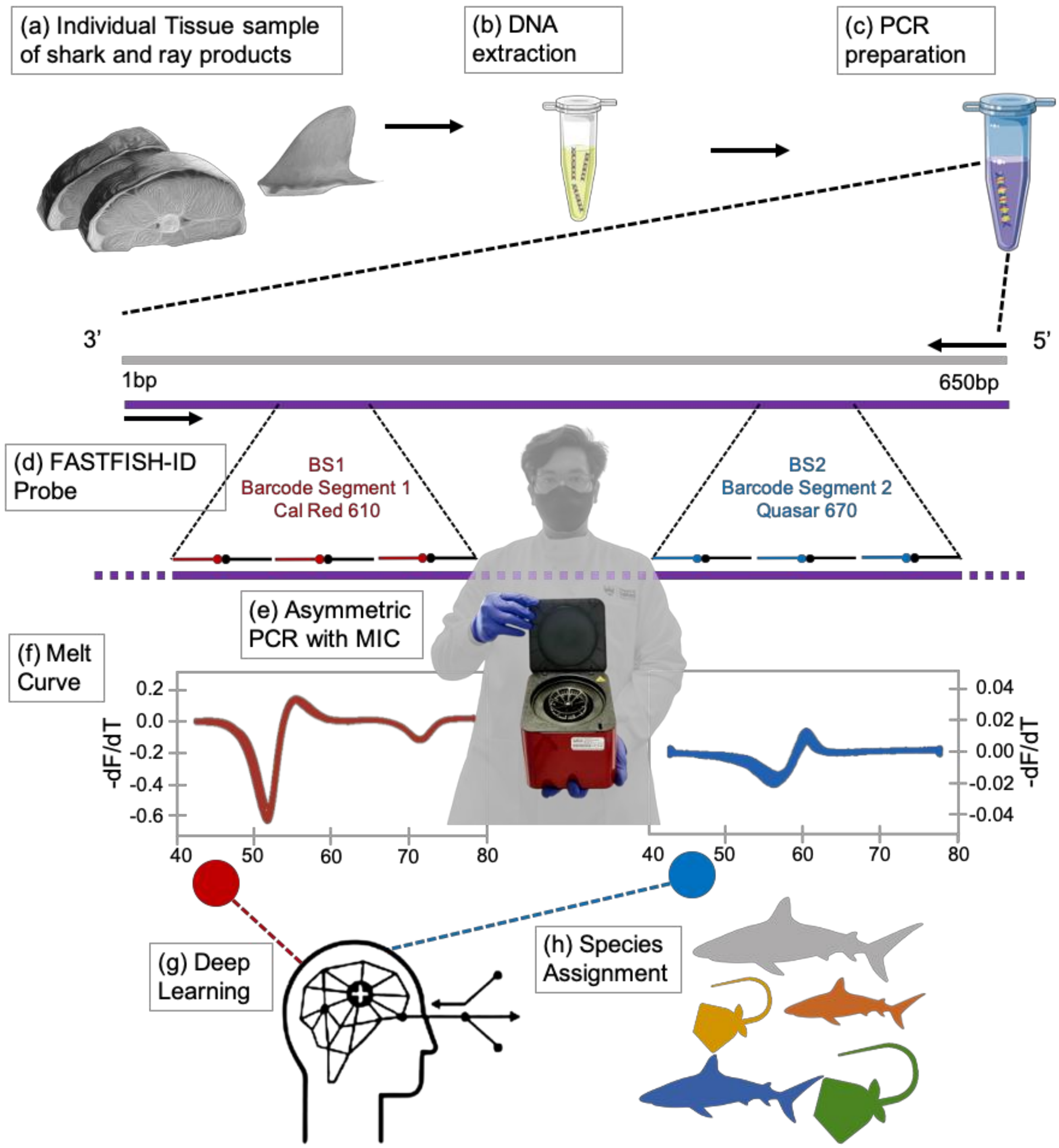


Figure S3.2. The fluorescent signatures in BS1 of 14 shark species.

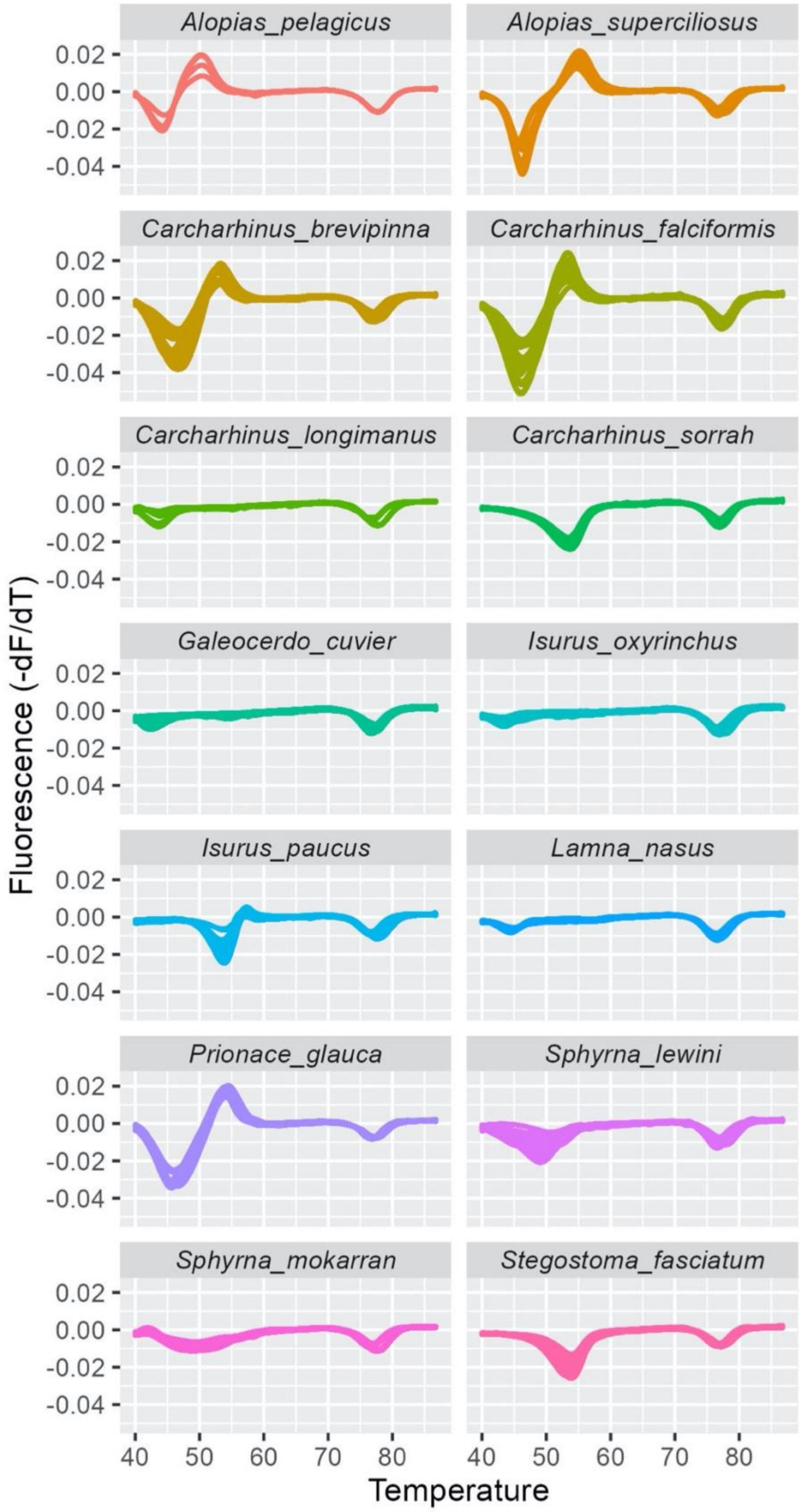


Figure S3.3. The fluorescent signatures in BS2 of 14 shark species.

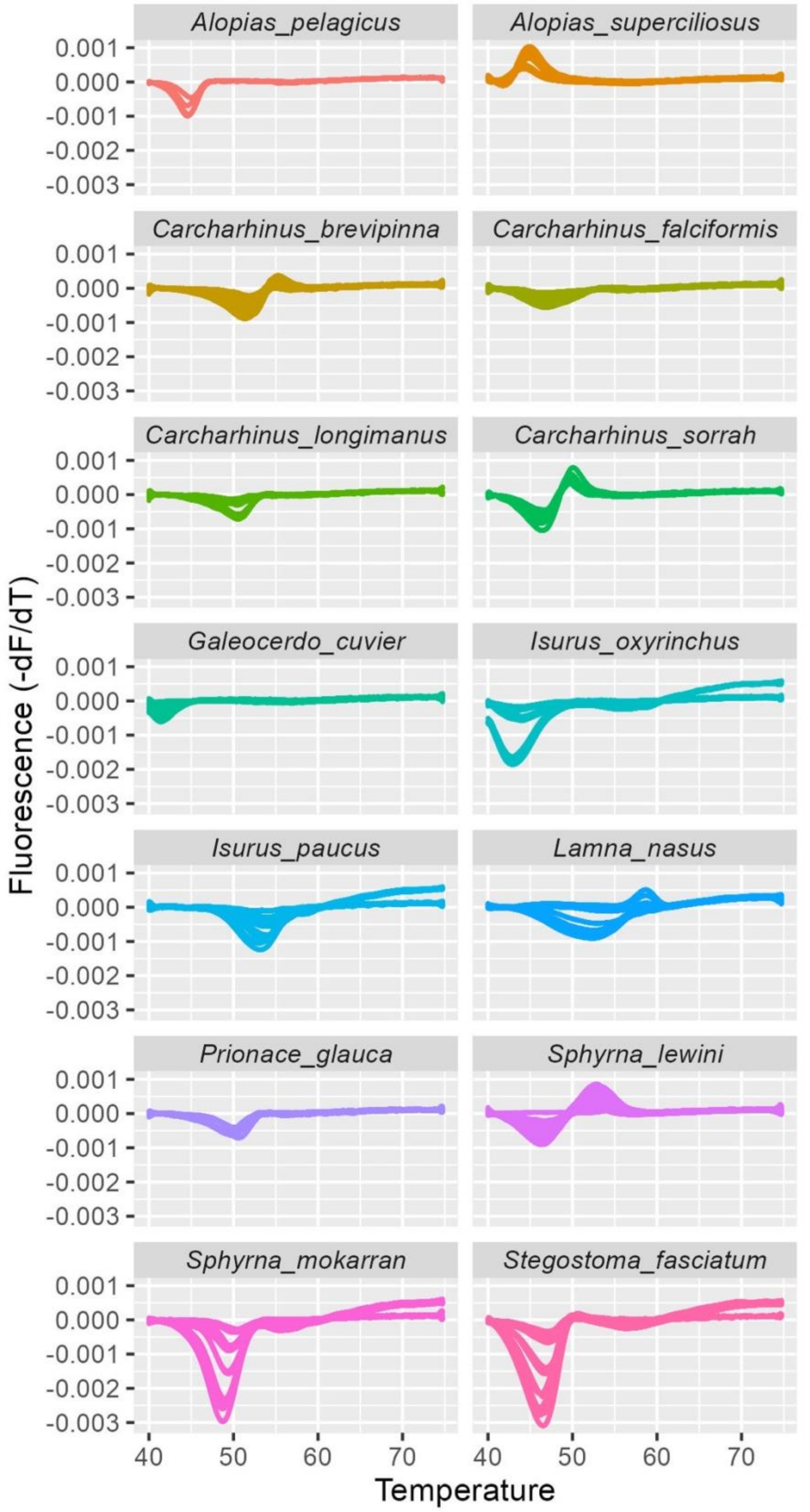


Figure S3.4. The fluorescent signatures in BS1 of 14 ray species.

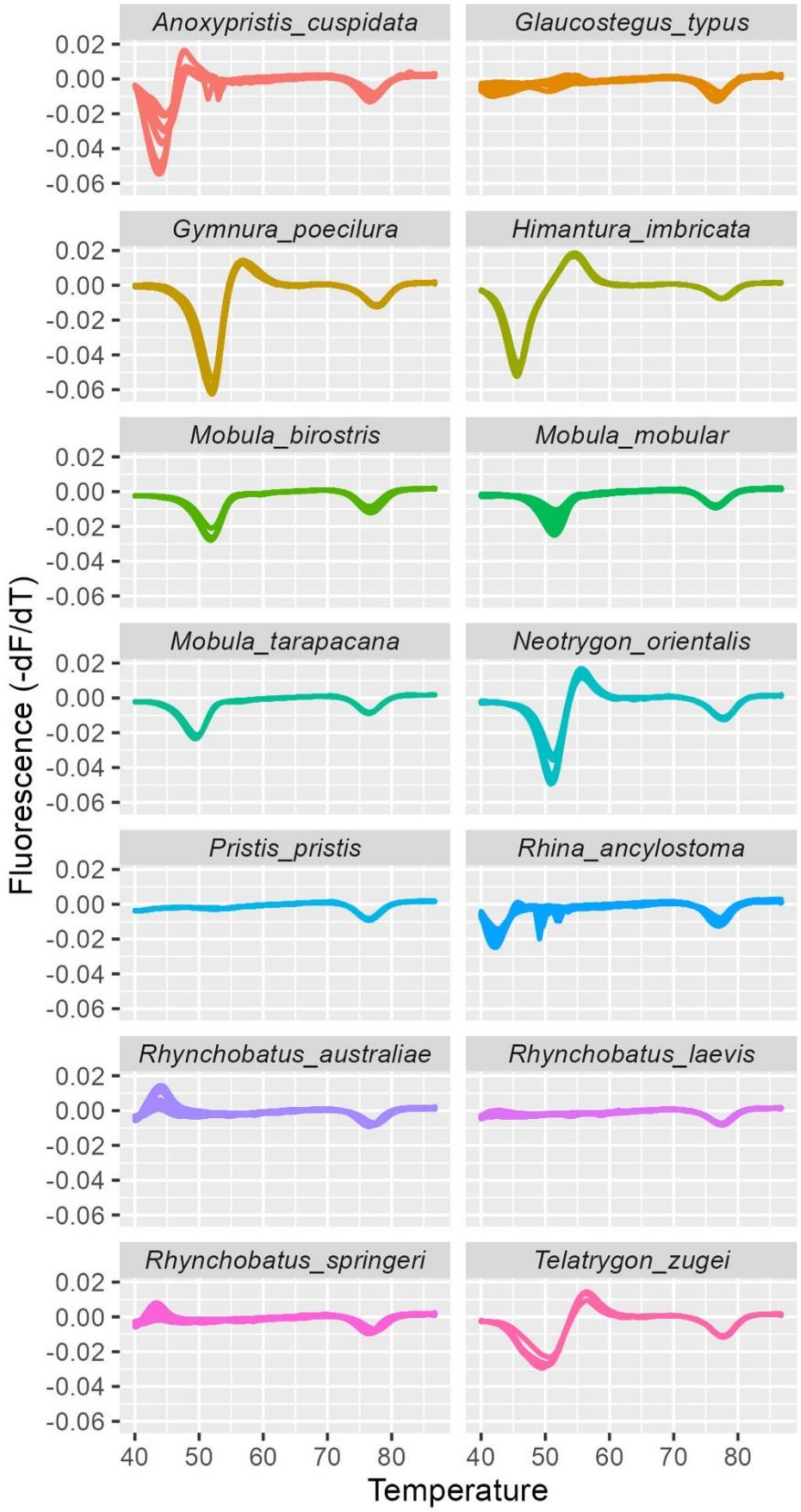


Figure S3.5. The fluorescent signatures in BS2 of 14 ray species.

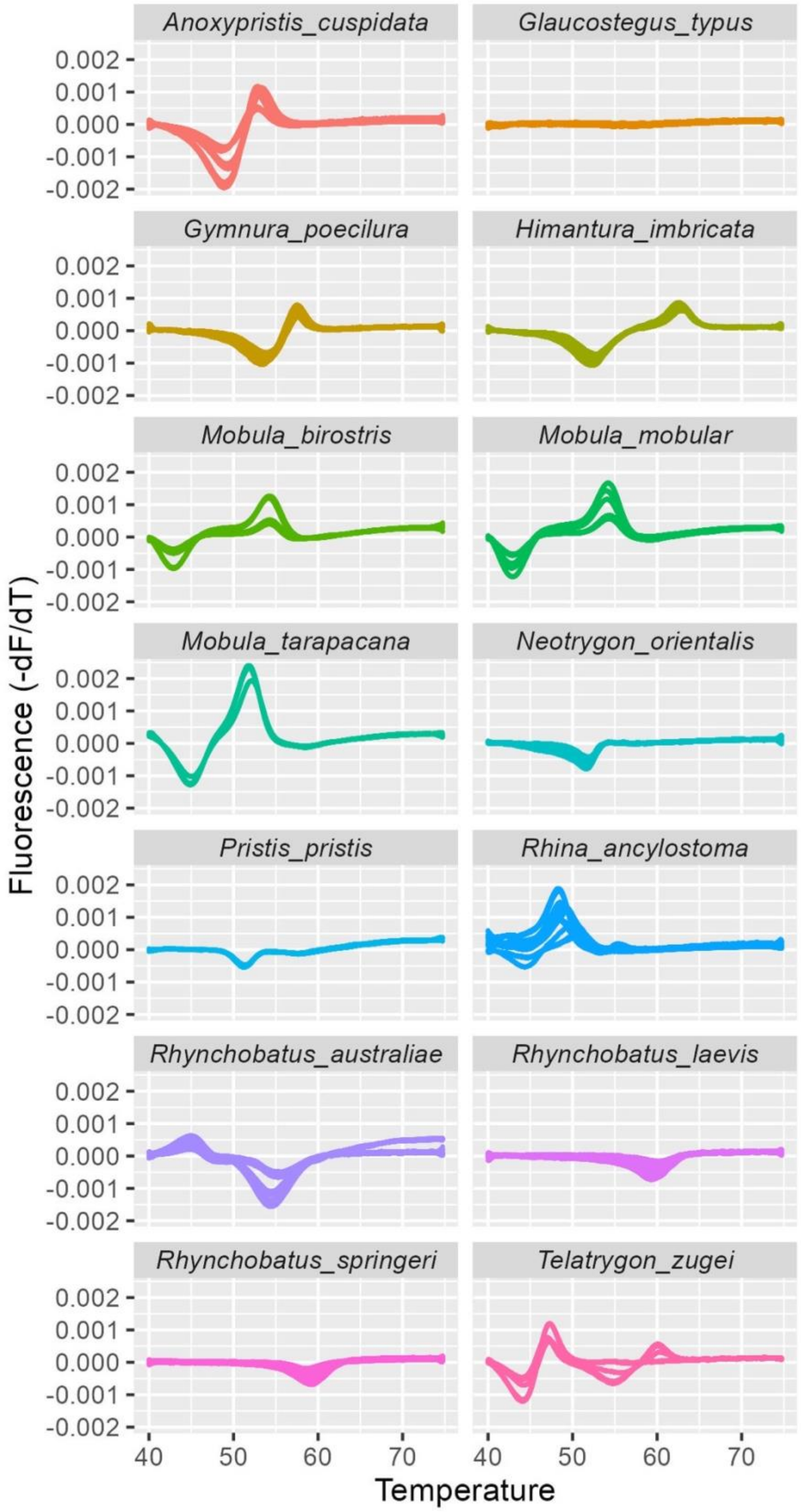


Figure S3.6. Some species which have a hybridization problem in the BS1 region. Those species only have "TM" signature (the right-most valley in the BS1, labelled with a green color), TM corresponds to ThermaMark^{TM}, an internal marker for correction of artefactual temperature variation.

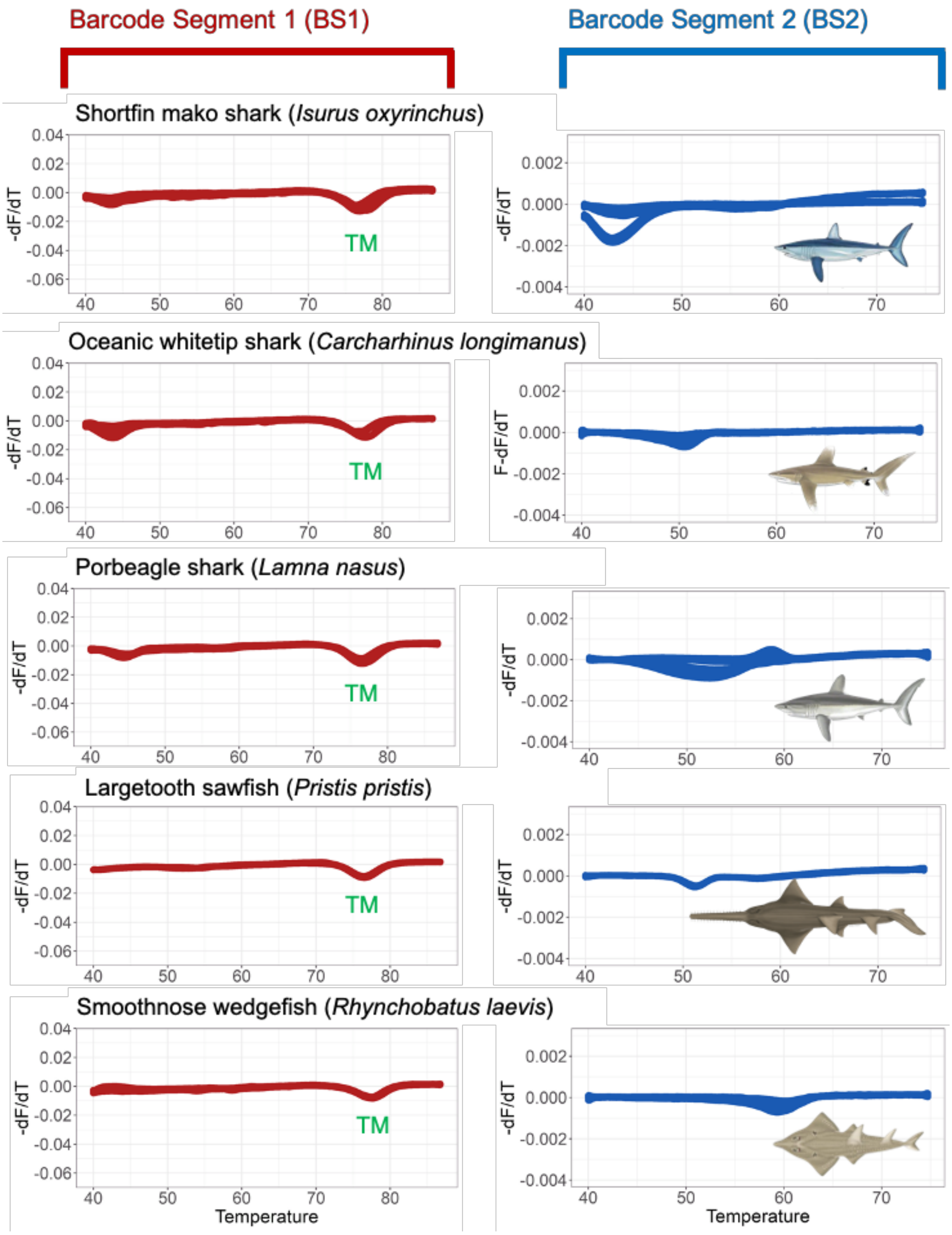


Table S3.1. Sample details used on the training datasets including Condition (processed/fresh), Part (of the animal), Species, ID (number), no. of replications and Sequencing technology used to identify the species.

Condition	**Part**	**Species**	**ID**	**Replication**	**Sequencing**
Processed	Dried fin	*Alopias pelagicus*	340	3	Sanger ~650bp
Processed	Dried fin	*Alopias pelagicus*	341	2	Sanger ~650bp
Processed	Dried fin	*Alopias superciliosus*	54	3	HTB ~313bp
Processed	Dried fin	*Alopias superciliosus*	345	3	Sanger ~650bp
Processed	Dried fin	*Alopias superciliosus*	346	3	Sanger ~650bp
Processed	Salted meat	*Alopias superciliosus*	366	3	HTB ~313bp
Processed	Dried fin	*Alopias superciliosus*	431	2	Sanger ~650bp
Processed	Unidentified	*Alopias superciliosus*	530	3	HTB ~313bp
Processed	Rostrum	*Anoxypristis cuspidata*	9	4	Sanger ~650bp
Processed	Dried fin	*Anoxypristis cuspidata*	22	3	Sanger ~650bp
Processed	Unidentified	*Anoxypristis cuspidata*	536	3	HTB ~313bp
Processed	Rostrum	*Anoxypristis cuspidata*	490	2	Sanger ~650bp
Fresh	Trunk	*Carcharhinus brevipinna*	77	3	HTB ~313bp
Fresh	Trunk	*Carcharhinus brevipinna*	78	3	Sanger ~650bp
Fresh	Trunk	*Carcharhinus brevipinna*	86	2	Sanger ~650bp
Fresh	Finless	*Carcharhinus brevipinna*	123	3	HTB ~313bp
Fresh	Whole	*Carcharhinus brevipinna*	321	1	Sanger ~650bp
Fresh	Whole	*Carcharhinus brevipinna*	323	3	Sanger ~650bp
Fresh	Whole	*Carcharhinus brevipinna*	324	3	Sanger ~650bp
Fresh	Whole	*Carcharhinus brevipinna*	334	3	Sanger ~650bp
Fresh	Whole	*Carcharhinus brevipinna*	475	1	Sanger ~650bp
Fresh	Trunk	*Carcharhinus falciformis*	3	3	HTB ~313bp

Condition	Part	Species	ID	Replication	Sequencing
Fresh	Trunk	*Carcharhinus falciformis*	4	3	HTB ~313bp
Fresh	Trunk	*Carcharhinus falciformis*	5	3	HTB ~313bp
Fresh	Trunk	*Carcharhinus falciformis*	6	3	HTB ~313bp
Fresh	Trunk	*Carcharhinus falciformis*	7	3	HTB ~313bp
Fresh	Trunk	*Carcharhinus falciformis*	43	3	Sanger ~650bp
Fresh	Whole	*Carcharhinus falciformis*	285	3	Sanger ~650bp
Fresh	Whole	*Carcharhinus falciformis*	293	2	Sanger ~650bp
Fresh	Whole	*Carcharhinus falciformis*	294X	3	Sanger ~650bp
Processed	Dried fin	*Carcharhinus longimanus*	25	3	Sanger ~650bp
Processed	Dried fin	*Carcharhinus longimanus*	53	3	Sanger ~650bp
Processed	Dried fin	*Carcharhinus longimanus*	342	2	Sanger ~650bp
Fresh	Trunk	*Carcharhinus sorrah*	29	3	HTB ~313bp
Fresh	Trunk	*Carcharhinus sorrah*	46	3	HTB ~313bp
Fresh	Whole	*Carcharhinus sorrah*	185	3	Sanger ~650bp
Fresh	Whole	*Carcharhinus sorrah*	319	1	Sanger ~650bp
Fresh	Whole	*Galeocerdo cuvier*	178	3	HTB ~313bp
Fresh	Whole	*Galeocerdo cuvier*	363	3	HTB ~313bp
Fresh	Fin	*Galeocerdo cuvier*	456	1	Sanger ~650bp
Processed	Dried fin	*Galeocerdo cuvier*	354	3	Sanger ~650bp
Processed	Dried fin	*Galeocerdo cuvier*	435	3	Sanger ~650bp
Processed	Dried fin	*Galeocerdo cuvier*	436	3	Sanger ~650bp
Processed	Dried fin	*Galeocerdo cuvier*	437	3	Sanger ~650bp
Processed	Teeth	*Galeocerdo cuvier*	439	3	Sanger ~650bp
Fresh	Whole	*Glaucostegus typus*	212	3	HTB ~313bp

Condition	Part	Species	ID	Replication	Sequencing
Fresh	Whole	*Glaucostegus typus*	268	5	Sanger ~650bp
Processed	Dried fin	*Glaucostegus typus*	11	3	HTB ~313bp
Processed	Dried skin	*Glaucostegus typus*	196	3	HTB ~313bp
Fresh	Whole	*Gymnura poecilura*	90	3	Sanger ~650bp
Fresh	Whole	*Gymnura poecilura*	91	3	Sanger ~650bp
Fresh	Whole	*Gymnura poecilura*	92	3	Sanger ~650bp
Fresh	Whole	*Himantura imbricata*	296	3	Sanger ~650bp
Fresh	Whole	*Himantura imbricata*	297	2	Sanger ~650bp
Processed	Dried fin	*Isurus oxyrinchus*	50	3	Sanger ~650bp
Processed	Dried fin	*Isurus oxyrinchus*	343	3	Sanger ~650bp
Processed	Dried fin	*Isurus oxyrinchus*	344	2	Sanger ~650bp
Processed	Dried fin	*Isurus oxyrinchus*	384	3	HTB ~313bp
Processed	Dried fin	*Isurus oxyrinchus*	421	3	HTB ~313bp
Processed	Unidentified	*Isurus oxyrinchus*	519	3	Sanger ~650bp
Processed	Unidentified	*Isurus oxyrinchus*	521	2	Sanger ~650bp
Processed	Dried fin	*Isurus paucus*	20	3	Sanger ~650bp
Processed	Dried fin	*Isurus paucus*	52	3	Sanger ~650bp
Processed	Dried fin	*Isurus paucus*	338	3	Sanger ~650bp
Processed	Dried fin	*Isurus paucus*	339	2	Sanger ~650bp
Processed	Unidentified	*Isurus paucus*	528	3	HTB ~313bp
Processed	Unidentified	*Isurus paucus*	533	3	HTB ~313bp
Processed	Dried fin	*Lamna nasus*	24	3	HTB ~313bp
Processed	Dried fin	*Lamna nasus*	505	3	HTB ~313bp
Processed	Dried fin	*Lamna nasus*	506	3	HTB ~313bp
Processed	Unidentified	*Lamna nasus*	527	3	HTB ~313bp
Processed	Salted meat	*Mobula birostris*	370	3	HTB ~313bp
Processed	Gill racker	*Mobula birostris*	412	3	HTB ~313bp
Processed	Gill racker	*Mobula mobular*	448	3	HTB ~313bp
Processed	Gill racker	*Mobula mobular*	449	3	HTB ~313bp
Processed	Gill racker	*Mobula mobular*	450	3	HTB ~313bp

Condition	Part	Species	ID	Replication	Sequencing
Processed	Gill racker	*Mobula mobular*	451	3	HTB ~313bp
Processed	Cartillage	*Mobula tarapacana*	12	3	HTB ~313bp
Fresh	Whole	*Neotrygon orientalis*	240	3	Sanger ~650bp
Fresh	Whole	*Neotrygon orientalis*	241	1	Sanger ~650bp
Fresh	Whole	*Neotrygon orientalis*	244	3	Sanger ~650bp
Fresh	Trunk	*Prionace glauca*	413	3	Sanger ~650bp
Processed	Dried fin	*Prionace glauca*	355	3	Sanger ~650bp
Processed	Dried fin	*Prionace glauca*	356	3	Sanger ~650bp
Processed	Unidentified	*Pristis pristis*	550	3	HTB ~313bp
Fresh	Whole	*Rhina ancylostoma*	276	3	Sanger ~650bp
Fresh	Whole	*Rhina ancylostoma*	211	3	Sanger ~650bp
Processed	Dried fin	*Rhina ancylostoma*	27	3	Sanger ~650bp
Processed	Dried skin	*Rhina ancylostoma*	48	4	Sanger ~650bp
Processed	Meat	*Rhina ancylostoma*	247	3	HTB ~313bp
Fresh	Whole	*Rhynchobatus australiae*	101	3	Sanger ~650bp
Fresh	Finless	*Rhynchobatus australiae*	175	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus australiae*	213	2	Sanger ~650bp
Fresh	Whole	*Rhynchobatus australiae*	229	1	HTB ~313bp
Fresh	Whole	*Rhynchobatus australiae*	259	1	HTB ~313bp
Fresh	Whole	*Rhynchobatus australiae*	279	3	Sanger ~650bp
Processed	Dried fin	*Rhynchobatus australiae*	424	3	HTB ~313bp
Fresh	Whole	*Rhynchobatus laevis*	35	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus laevis*	151	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus laevis*	152	3	Sanger ~650bp
Fresh	Finless	*Rhynchobatus laevis*	177	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	189	3	Sanger ~650bp

Condition	Part	Species	ID	Replication	Sequencing
Fresh	Whole	*Rhynchobatus springeri*	214	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	215	1	HTB ~313bp
Fresh	Whole	*Rhynchobatus springeri*	221	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	224	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	226	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	258	3	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	274	3	Sanger ~650bp
Fresh	Finless	*Sphyrna lewini*	112	3	Sanger ~650bp
Fresh	Whole	*Sphyrna lewini*	115	3	Sanger ~650bp
Fresh	Whole	*Sphyrna lewini*	121	3	Sanger ~650bp
Fresh	Finless	*Sphyrna lewini*	122	3	HTB ~313bp
Fresh	Finless	*Sphyrna lewini*	126	3	Sanger ~650bp
Fresh	Whole	*Sphyrna lewini*	476	3	Sanger ~650bp
Processed	Dried fin	*Sphyrna lewini*	16	3	HTB ~313bp
Processed	Dried fin	*Sphyrna lewini*	426	1	Sanger ~650bp
Fresh	Finless	*Sphyrna mokarran*	113	3	Sanger ~650bp
Processed	Cartillage	*Sphyrna mokarran*	13	3	HTB ~313bp
Processed	Dried fin	*Sphyrna mokarran*	21	3	Sanger ~650bp
Processed	Dried skin	*Sphyrna mokarran*	197	3	HTB ~313bp
Processed	Salted meat	*Sphyrna mokarran*	367	3	HTB ~313bp
Processed	Dried fin	*Sphyrna mokarran*	418	2	Sanger ~650bp
Fresh	Whole	*Stegostoma fasciatum*	133	3	HTB ~313bp
Fresh	Trunk	*Stegostoma fasciatum*	179	3	HTB ~313bp
Fresh	Trunk	*Stegostoma fasciatum*	180	3	HTB ~313bp

Condition	Part	Species	ID	Replication	Sequencing
Fresh	Trunk	*Stegostoma fasciatum*	181	3	Sanger ~650bp
Processed	Dried fin	*Stegostoma fasciatum*	583	1	Sanger ~650bp
Fresh	Whole	*Telatrygon zugei*	198	3	Sanger ~650bp
Fresh	Whole	*Telatrygon zugei*	245	2	Sanger ~650bp

Table S3.2. Sample details used on the testing datasets including Condition (processed/fresh), Part (of the animal), Species, ID (number), no. of replications and Sequencing technology used to identify the species.

Condition	Part	Species	ID	Replication	Sequencing
Processed	Dried fin	*Alopias pelagicus*	340	1	Sanger ~650bp
Processed	Dried fin	*Alopias superciliosus*	431	1	Sanger ~650bp
Processed	Unidentified	*Alopias superciliosus*	535	1	HTB ~313bp
Processed	Unidentified	*Anoxypristis cuspidata*	536	1	HTB ~313bp
Fresh	Whole	*Carcharhinus brevipinna*	317	1	HTB ~313bp
Fresh	Whole	*Carcharhinus brevipinna*	321	1	Sanger ~650bp
Fresh	Whole	*Carcharhinus brevipinna*	322	1	HTB ~313bp
Fresh	Whole	*Carcharhinus brevipinna*	326	1	HTB ~313bp
Fresh	Whole	*Carcharhinus brevipinna*	475	1	Sanger ~650bp
Fresh	Trunk	*Carcharhinus falciformis*	43	1	Sanger ~650bp
Fresh	Trunk	*Carcharhinus falciformis*	4	1	HTB ~313bp
Fresh	Trunk	*Carcharhinus falciformis*	19	1	HTB ~313bp
Fresh	Trunk	*Carcharhinus falciformis*	58	1	HTB ~313bp
Processed	Dried fin	*Carcharhinus longimanus*	342	1	Sanger ~650bp
Processed	Unidentified	*Carcharhinus longimanus*	522	1	HTB ~313bp
Processed	Unidentified	*Carcharhinus longimanus*	523	1	HTB ~313bp
Processed	Unidentified	*Carcharhinus longimanus*	524	1	HTB ~313bp
Fresh	Whole	*Carcharhinus sorrah*	304	1	Sanger ~650bp
Processed	Oil	*Galeocerdo cuvier*	396	1	HTB ~313bp
Processed	Dried fin	*Galeocerdo cuvier*	432	1	HTB ~313bp
Processed	Dried fin	*Galeocerdo cuvier*	433	1	HTB ~313bp
Processed	Dried fin	*Galeocerdo cuvier*	434	1	HTB ~313bp

Condition	Part	Species	ID	Replication	Sequencing
Processed	Dried skin	*Galeocerdo cuvier*	441	1	Sanger ~650bp
Fresh	Whole	*Glaucostegus typus*	272	1	Sanger ~650bp
Fresh	Whole	*Glaucostegus typus*	275	1	HTB ~313bp
Processed	Dried fin	*Glaucostegus typus*	422	1	HTB ~313bp
Processed	Dried fin	*Glaucostegus typus*	428	1	HTB ~313bp
Processed	Unidentified	*Glaucostegus typus*	537	1	HTB ~313bp
Fresh	Whole	*Gymnura poecilura*	88	1	Sanger ~650bp
Fresh	Whole	*Gymnura poecilura*	89	1	Sanger ~650bp
Fresh	Whole	*Himantura imbricata*	297	1	Sanger ~650bp
Processed	Dried fin	*Isurus oxyrinchus*	344	1	Sanger ~650bp
Processed	Unidentified	*Isurus oxyrinchus*	531	1	HTB ~313bp
Processed	Dried fin	*Isurus paucus*	339	1	Sanger ~650bp
Processed	Dried fin	*Lamna nasus*	24	1	HTB ~313bp
Processed	Unidentified	*Lamna nasus*	529	1	HTB ~313bp
Processed	Salted meat	*Mobula birostris*	370	1	HTB ~313bp
Processed	Gill racker	*Mobula mobular*	451	1	HTB ~313bp
Processed	Cartillage	*Mobula tarapacana*	12	1	HTB ~313bp
Fresh	Whole	*Neotrygon orientalis*	242	1	Sanger ~650bp
Fresh	Trunk	*Prionace glauca*	414	1	HTB ~313bp
Fresh	Trunk	*Prionace glauca*	416	1	Sanger ~650bp
Fresh	Trunk	*Prionace glauca*	417	1	HTB ~313bp
Processed	Dried fin unskin	*Prionace glauca*	399	1	HTB ~313bp
Processed	Dried fin	*Prionace glauca*	410	1	HTB ~313bp
Processed	Unidentified	*Pristis pristis*	550	1	HTB ~313bp
Processed	Dried fin	*Rhina ancylostoma*	14	1	Sanger ~650bp
Processed	Dried skin	*Rhina ancylostoma*	48	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus australiae*	213	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus laevis*	39	1	Sanger ~650bp
Fresh	Finless	*Rhynchobatus laevis*	176	1	HTB ~313bp

Condition	Part	Species	ID	Replication	Sequencing
Processed	Unidentified	*Rhynchobatus laevis*	534	1	HTB ~313bp
Fresh	Whole	*Rhynchobatus springeri*	217	1	HTB ~313bp
Fresh	Whole	*Rhynchobatus springeri*	224	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	225	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	226	1	Sanger ~650bp
Fresh	Whole	*Rhynchobatus springeri*	223B	1	Sanger ~650bp
Fresh	Finless	*Sphyrna lewini*	125	1	HTB ~313bp
Fresh	Trunk	*Sphyrna lewini*	155	1	HTB ~313bp
Fresh	Trunk	*Sphyrna lewini*	156	1	HTB ~313bp
Fresh	Whole	*Sphyrna lewini*	160	1	HTB ~313bp
Fresh	Whole	*Sphyrna lewini*	234	1	Sanger ~650bp
Processed	Dried fin	*Sphyrna lewini*	419	1	Sanger ~650bp
Processed	Dried fin	*Sphyrna lewini*	426	1	Sanger ~650bp
Processed	Dried fin	*Sphyrna mokarran*	418	1	Sanger ~650bp
Processed	Dried fin	*Sphyrna mokarran*	420	1	HTB ~313bp
Processed	Dried skin	*Stegostoma fasciatum*	195	1	HTB ~313bp
Fresh	Whole	*Telatrygon zugei*	245	1	Sanger ~650bp

Table S3.3. Initial value of hyper-parameters in searching for the best deep learning model using grid search method

Parameters	**Definition**	**Value**
activation	The activation function of learning model	"Rectifier", "Maxout", "Tanh", "RectifierWithDropout", "MaxoutWithDropout" and "TanhWithDropout"
hidden	Number of learning layers	[100, 100, 100], [200, 200, 200] and [500, 500, 500]
epochs	Number of times to iterate (stream) the dataset	50, 100, 200, 300 and 500
rho	The adaptive learning rate time decay factor	0.9, 0.95, 0.99 and 0.999
epsilon	The adaptive learning rate time smoothing factor to avoid dividing by zero	1e-10, 1e-8, 1e-6 and 1e-4
input_dropout_ratio	The input layer dropout ratio to improve generalisation. Suggested values are 0.1 or 0.2	0, 0.1 and 0.2
l1	The L1 regularization to add stability and improve generalisation	0, 0.00001 and 0.0001
l2	The L2 regularization to add stability and improve generalisation	0, 0.00001 and 0.0001
max_w2	The constraint for the squared sum of the incoming weights per unit	10, 100, 1000 and 3.4028235e+38

Table S3.4. Stopping criteria in searching the best deep learning model

Criteria	Definition	Value
strategy	strategy to perform a random search of all the combinations of your hyperparameters	RandomDiscrete
max_models	The maximum number of generated models	100,000
max_runtime_secs	The maximum run time in second	43,200 seconds (12 hours)
stopping_tolerance	Stop if MSE hasn't improved by the value	0.001
stopping_rounds	Number of models to compare MSE improvement	20
seed	Seed number to control randomness	1234

Table S3.5. Variable importance in recognizing fluorescent signatures of species

Barcode segment	Variable	Relative importance	Scaled importance	Percentage
BS1	C5	1	1	1.87E-04
BS1	C13	0.97	0.97	1.81E-04
BS1	C15	0.96	0.96	1.80E-04
BS1	C17	0.97	0.97	1.82E-04
…	…	…	…	…
BS1	C2635	0.53	0.53	9.90E-05
BS2	C4678	0.98	0.98	1.82E-04
BS2	C6741	0.52	0.52	9.81E-05
BS2	C6747	0.53	0.53	9.92E-05
BS2	C6748	0.53	0.53	9.91E-05
BS2	C6750	0.53	0.53	9.90E-05

Table S3.6. Result of grid search in finding the best deep learning model

No	Model ID	Accuracy	Activation function	Epochs	Epsilon	Hidden layers	Input dropout ratio	L1	L2	Max w2	Rho
1	dl_grid_model_17	0.98	RectifierWithDropout	500	1.00E-08	[500, 500, 500]	0.2	0	0.0001	1000	0.9
2	dl_grid_model_170	0.98	Maxout	300	1.00E-06	[500, 500, 500]	0.2	0	0	100	0.9
3	dl_grid_model_7	0.98	MaxoutWithDropout	500	1.00E-06	[100, 100, 100]	0	0	0.0001	100	0.95
4	dl_grid_model_104	0.97	Tanh	500	1.00E-10	[100, 100, 100]	0.2	0	0	10	0.95
5	dl_grid_model_107	0.97	TanhWithDropout	300	1.00E-06	[500, 500, 500]	0	1E-05	1E-05	1000	0.95
...	...	...	...	...	...	...	...	...	...	...	...
7	dl_grid_model_32	0.01	Rectifier	300	1.00E-04	[100, 100, 100]	0.1	0	0	10	1
8	dl_grid_model_195	0.00	Rectifier	100	1.00E-04	[500, 500, 500]	0	0	0	10	1
9	dl_grid_model_247	0.00	RectifierWithDropout	200	1.00E-06	[500, 500, 500]	0	0	0	1000	1
10	dl_grid_model_260	0.00	RectifierWithDropout	300	1.00E-04	[200, 200, 200]	0	0	1E-05	100	0.95
11	dl_grid_model_66	0.00	RectifierWithDropout	50	1.00E-04	[200, 200, 200]	0	0	0.0001	100	0.95

Table S3.7. Assignment scoring of 28 species of sharks and rays

No.	Actual	Prediction		SCORE	*Alopias_pelagicus*	*Alopias_superciliosus*	*Anoxypristis_cuspidata*	*Carcharhinus_brevipinna*	*Carcharhinus_falciformis*	*Carcharhinus_longimanus*	*Carcharhinus_sorrah*	*Galeocerdo_cuvier*	*Glaucostegus_typus*	*Gymnura_poecilura*	*Himantura_imbricata*	*Isurus_oxyrinchus*	*Isurus_paucus*	*Lamna_nasus*	*Mobula_birostris*	*Mobula_mobular*	*Mobula_tarapacana*	*Neotrygon_orientalis*	*Prionace_glauca*	*Pristis_pristis*	*Rhina_ancylostoma*	*Rhynchobatus_australiae*	*Rhynchobatus_laevis*	*Rhynchobatus_springeri*	*Sphyrna_lewini*	*Sphyrna_mokarran*	*Stegostoma_fasciatum*	*Telatrygon_zugei*
1	*Glaucostegus_typus*	*Glaucostegus_typus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	*Rhina_ancylostoma*	*Rhina_ancylostoma*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	*Rhynchobatus_laevis*	*Rhynchobatus_laevis*	Match	0.545	0.004	0.001	0.000	0.000	0.001	0.000	0.001	0.319	0.102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.000	0.002	0.001	0.545	0.000	0.019	0.000	0.000	0.000
4	*Rhynchobatus_springeri*	*Rhynchobatus_springeri*	Match	0.999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.999	0.000	0.000	0.000	0.000
5	*Rhynchobatus_springeri*	*Rhynchobatus_springeri*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
6	*Gymnura_poecilura*	*Gymnura_poecilura*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	*Gymnura_poecilura*	*Gymnura_poecilura*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	*Neotrygon_orientalis*	*Neotrygon_orientalis*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	*Sphyrna_lewini*	*Sphyrna_lewini*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
10	*Sphyrna_lewini*	*Sphyrna_lewini*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
11	*Carcharhinus_sorrah*	*Stegostoma_fasciatum*	Mismatch	0.975	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.975	0.000
12	*Galeocerdo_cuvier*	*Galeocerdo_cuvier*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	*Prionace_glauca*	*Prionace_glauca*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	*Rhynchobatus_springeri*	*Rhynchobatus_springeri*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
15	*Rhynchobatus_springeri*	*Rhynchobatus_springeri*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
16	*Sphyrna_lewini*	*Sphyrna_lewini*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
17	*Carcharhinus_brevipinna*	*Carcharhinus_brevipinna*	Match	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	*Carcharhinus_brevipinna*	*Carcharhinus_brevipinna*	Match	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	*Rhina_ancylostoma*	*Rhina_ancylostoma*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	*Alopias_superciliosus*	*Alopias_superciliosus*	Match	1.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	*Carcharhinus_longimanus*	*Carcharhinus_longimanus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	*Himantura_imbricata*	*Himantura_imbricata*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	*Isurus_oxyrinchus*	*Isurus_oxyrinchus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	*Isurus_paucus*	*Isurus_paucus*	Match	0.997	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	*Rhynchobatus_australiae*	*Rhynchobatus_australiae*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
26	*Sphyrna_mokarran*	*Glaucostegus_typus*	Mismatch	0.802	0.002	0.000	0.000	0.001	0.000	0.190	0.000	0.000	0.802	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
27	*Telatrygon_zugei*	*Telatrygon_zugei*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
28	*Carcharhinus_brevipinna*	*Carcharhinus_brevipinna*	Match	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	*Carcharhinus_brevipinna*	*Carcharhinus_brevipinna*	Match	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	*Carcharhinus_brevipinna*	*Carcharhinus_brevipinna*	Match	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	*Carcharhinus_falciformis*	*Carcharhinus_falciformis*	Match	0.995	0.000	0.000	0.000	0.005	0.995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	*Galeocerdo_cuvier*	*Glaucostegus_typus*	Mismatch	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33	*Galeocerdo_cuvier*	*Glaucostegus_typus*	Mismatch	0.923	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.923	0.000	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34	*Galeocerdo_cuvier*	*Glaucostegus_typus*	Mismatch	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35	*Galeocerdo_cuvier*	*Glaucostegus_typus*	Mismatch	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	*Glaucostegus_typus*	*Glaucostegus_typus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	*Glaucostegus_typus*	*Glaucostegus_typus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	*Glaucostegus_typus*	*Glaucostegus_typus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	*Glaucostegus_typus*	*Glaucostegus_typus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	*Prionace_glauca*	*Prionace_glauca*	Match	0.929	0.000	0.000	0.000	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.929	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	*Prionace_glauca*	*Carcharhinus_brevipinna*	Mismatch	0.878	0.000	0.000	0.000	0.878	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	*Prionace_glauca*	*Prionace_glauca*	Match	0.663	0.000	0.000	0.000	0.337	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.663	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	*Prionace_glauca*	*Prionace_glauca*	Match	0.735	0.000	0.000	0.000	0.192	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.735	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	*Rhynchobatus_laevis*	*Isurus_paucus*	Mismatch	0.740	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.740	0.000	0.003	0.004	0.001	0.000	0.000	0.004	0.014	0.077	0.136	0.009	0.000	0.000	0.001	0.000
45	*Rhynchobatus_laevis*	*Rhynchobatus_laevis*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
46	*Rhynchobatus_springeri*	*Pristis_pristis*	Mismatch	0.583	0.000	0.369	0.002	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.003	0.000	0.001	0.000	0.003	0.024	0.005	0.000	0.002	0.583	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000
47	*Sphyrna_lewini*	*Mobula_tarapacana*	Mismatch	0.724	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.724	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.276	0.000	0.000	0.000
48	*Sphyrna_lewini*	*Sphyrna_lewini*	Match	0.785	0.000	0.000	0.009	0.000	0.005	0.000	0.004	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.021	0.009	0.156	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.785	0.005	0.003	0.000
49	*Sphyrna_lewini*	*Glaucostegus_typus*	Mismatch	0.914	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.914	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.083	0.000	0.000	0.000
50	*Sphyrna_lewini*	*Sphyrna_lewini*	Match	0.987	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.987	0.000	0.000	0.000
51	*Alopias_superciliosus*	*Alopias_superciliosus*	Match	0.608	0.000	0.608	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.392	0.000	0.000	0.000	0.000	0.000
52	*Carcharhinus_longimanus*	*Glaucostegus_typus*	Mismatch	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
53	*Carcharhinus_longimanus*	*Glaucostegus_typus*	Mismatch	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
54	*Carcharhinus_longimanus*	*Glaucostegus_typus*	Mismatch	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	*Isurus_oxyrinchus*	*Isurus_oxyrinchus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
56	*Sphyrna_mokarran*	*Sphyrna_mokarran*	Match	0.973	0.000	0.000	0.000	0.000	0.000	0.015	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.003	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.973	0.000	0.000
57	*Stegostoma_fasciatum*	*Stegostoma_fasciatum*	Match	0.523	0.000	0.000	0.000	0.000	0.000	0.000	0.477	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.523	0.000
58	*Alopias_pelagicus*	*Alopias_pelagicus*	Match	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59	*Anoxypristis_cuspidata*	*Anoxypristis_cuspidata*	Match	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	*Lamna_nasus*	*Lamna_nasus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	*Lamna_nasus*	*Lamna_nasus*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	*Mobula_birostris*	*Mobula_birostris*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	*Mobula_mobular*	*Mobula_mobular*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	*Mobula_tarapacana*	*Mobula_tarapacana*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	*Pristis_pristis*	*Pristis_pristis*	Match	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	*Carcharhinus_falciformis*	*Carcharhinus_falciformis*	Match	1.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	*Carcharhinus_falciformis*	*Carcharhinus_falciformis*	Match	1.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
68	*Carcharhinus_falciformis*	*Carcharhinus_falciformis*	Match	1.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Supplementary material – Chapter 4

Figure S4.1. Gel electrophoresis was used to validate the PCR products of dust samples, which were amplified using the Elas02 primer.

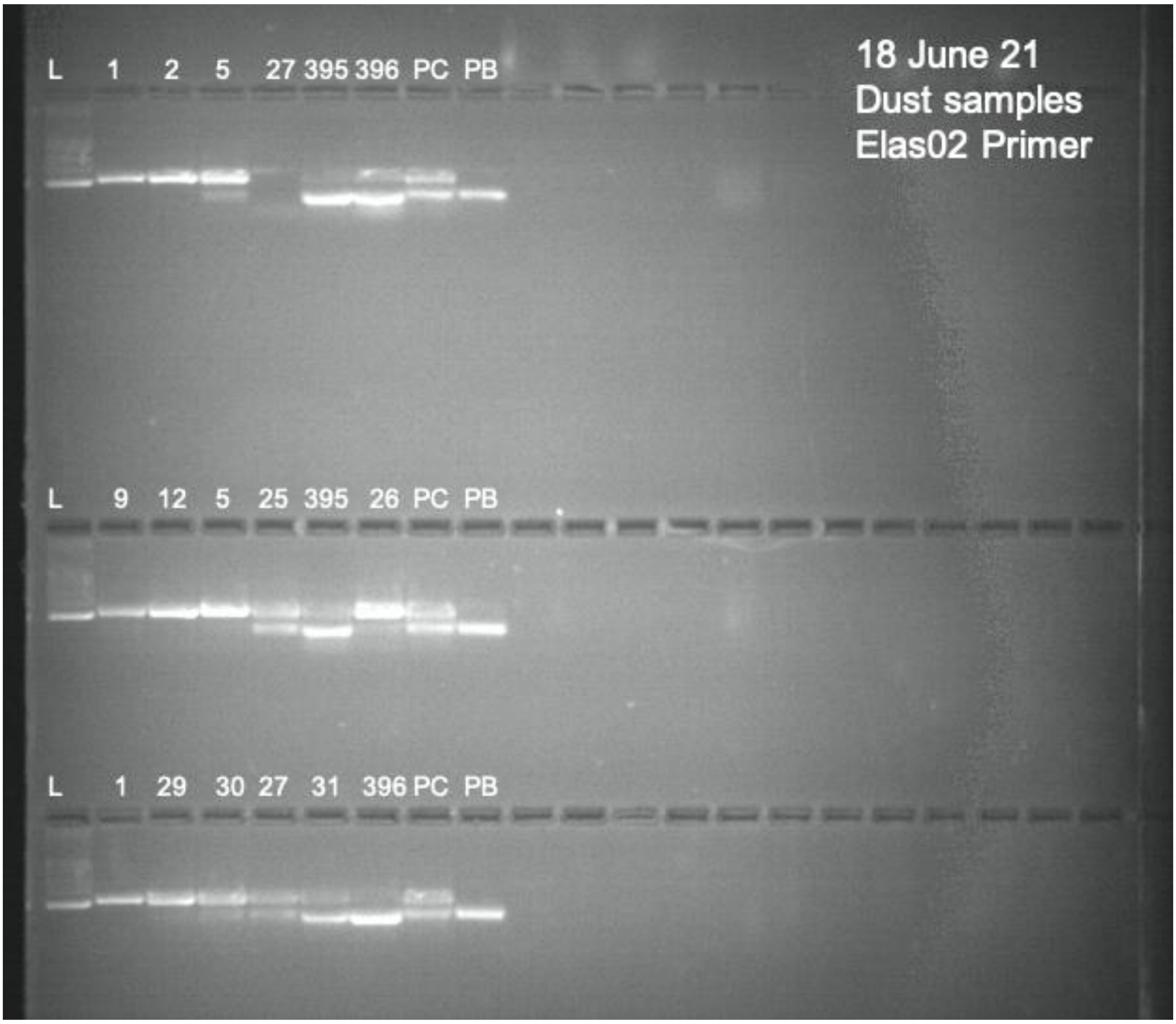


Figure S4.2. Gel electrophoresis was used to validate the PCR products of dust samples, which were amplified using the Leray-XT primer.

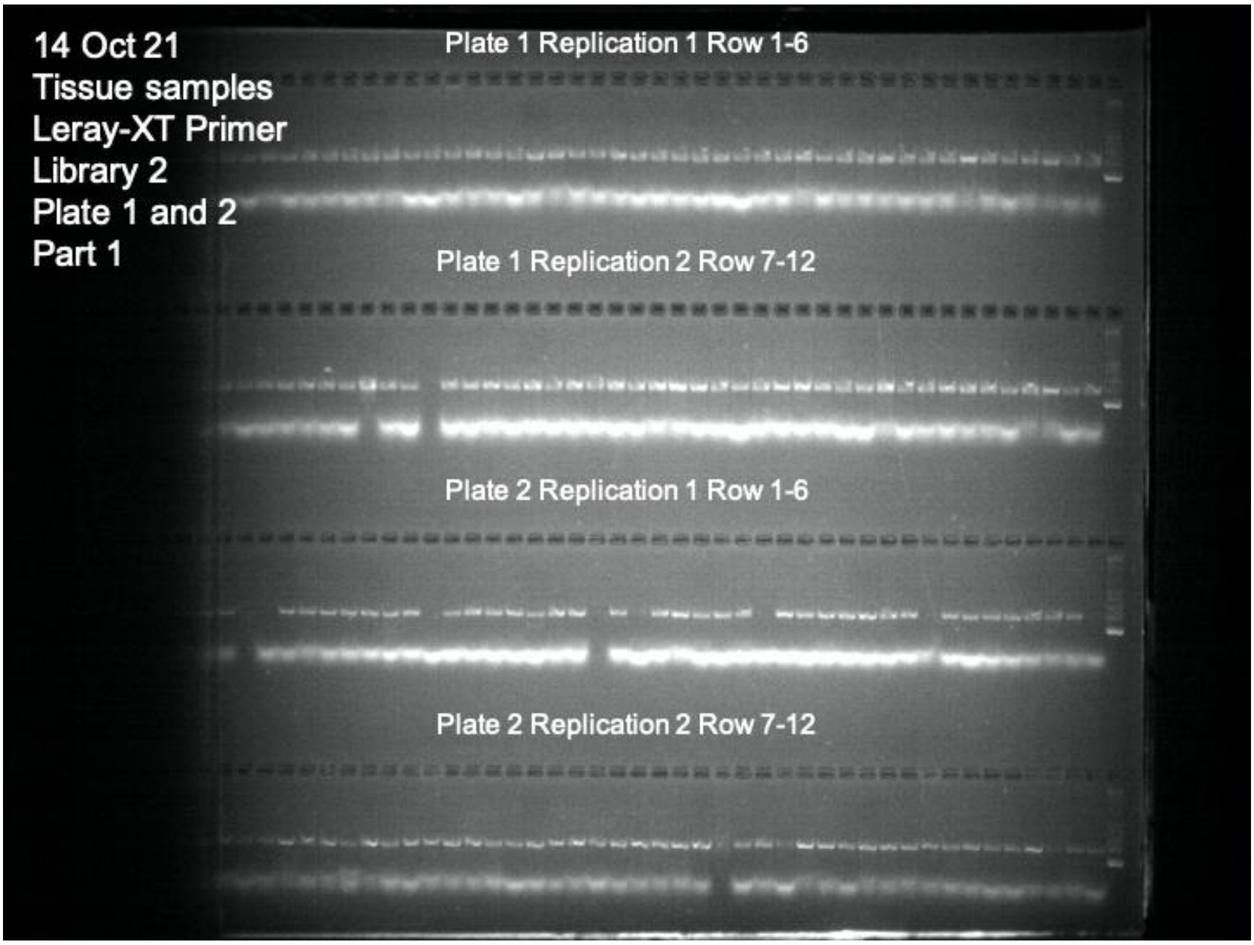
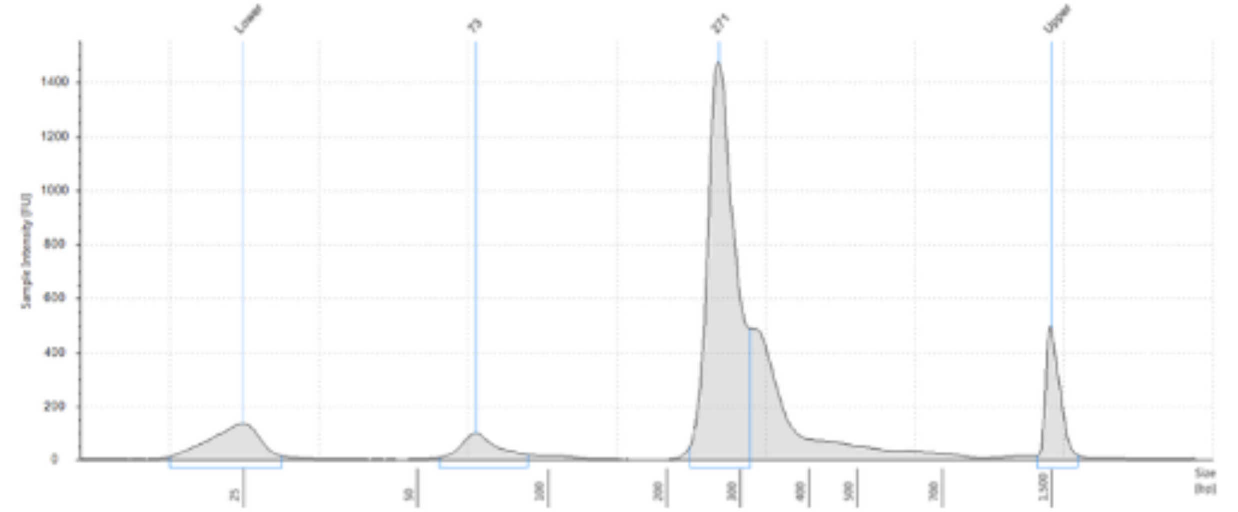


Figure S4.3. Before (a) and after (b) bead cleaning of dust's pool library on an Agilent™ tapestation.

(a) Library pool pre-clean



(b) Library pool post-clean

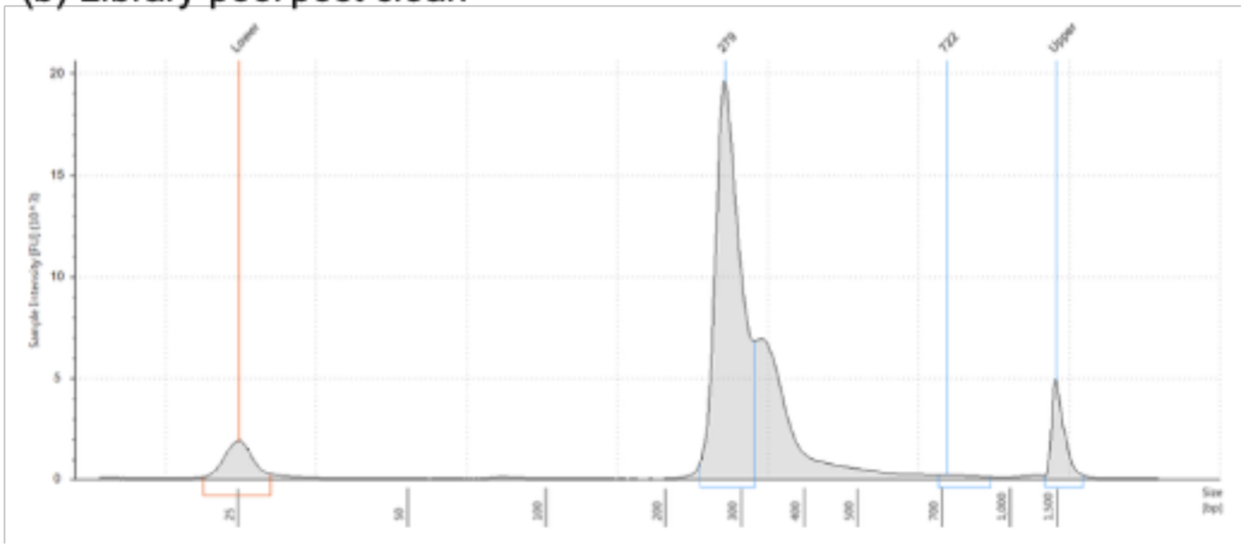


Figure S4.4. Before and after bead cleaning of tissue's pool library 1-3 (a-c) and adapter ligation (d) on an Agilent^{TM} tapestation.

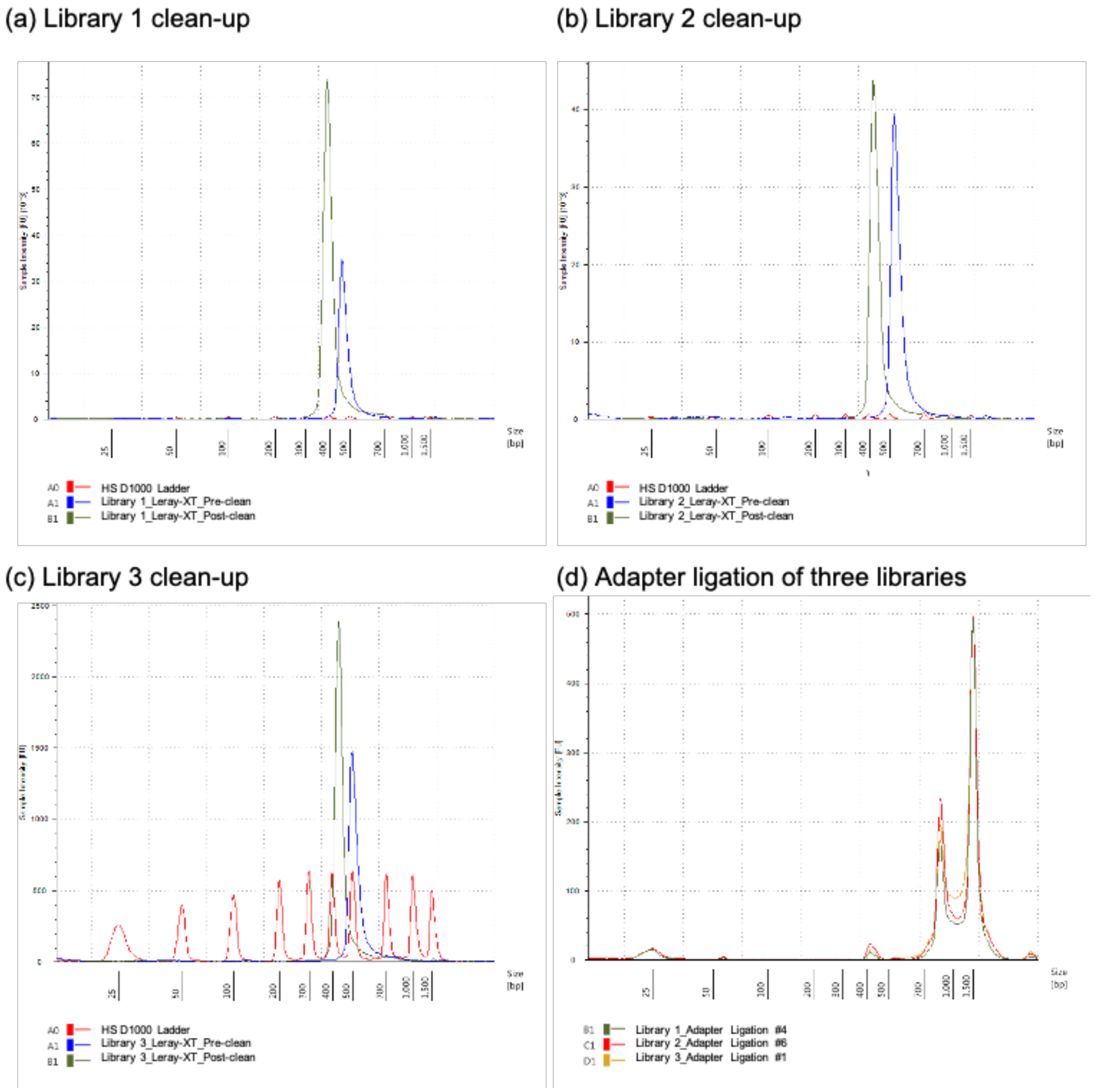


Figure S4.5. Adapter ligation of dust's pool library on an Agilent™ tapestation

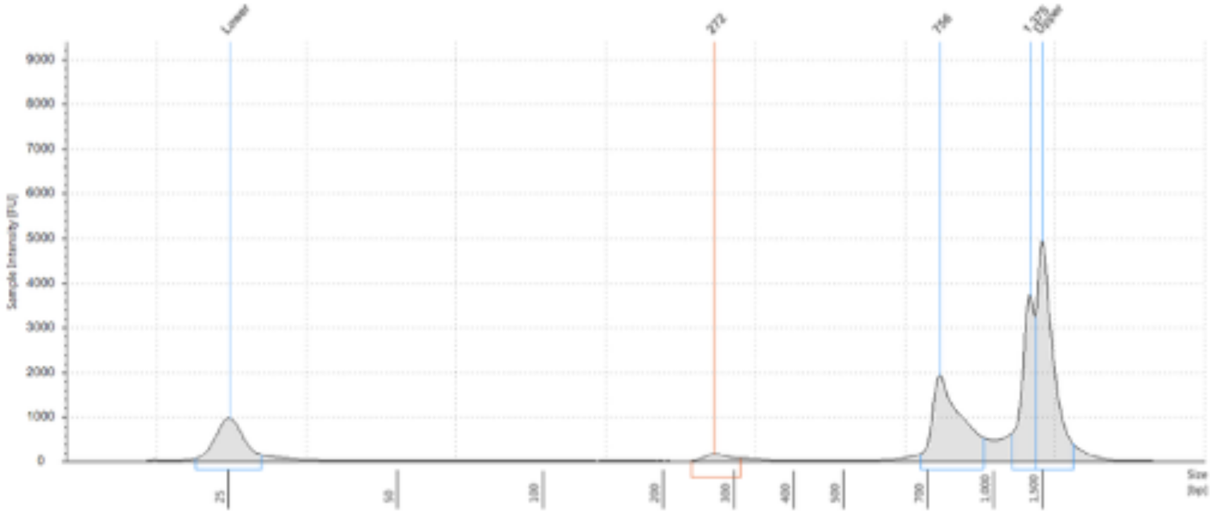


Figure S4.6. Final library quantification (preparing Illumina MiSeq™ Pool) using the NEBio Quant kit of dust's pool library on the Biomolecular Systems's Magnetic Induction Cycler™ (MIC).

qPCR Library Quantification -- Thu Jul 08 2021

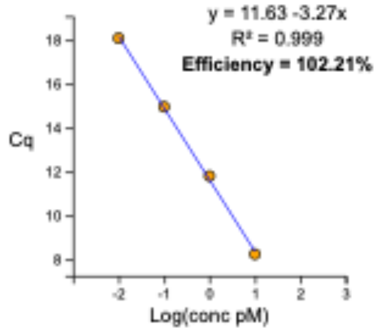
Summary

Standard Curve	Libraries
Efficiency: 102.21 %	1: Lib_POOLED_6nM (357 bp) 6.05 nM - Size corrected.
R^2: 0.999	2: Lib_POOLED_4nM_Vortex (357 bp) 4.31 nM - Size corrected.
slope: -3.27	

Detailed Input and Results

Standards

Use	Conc (pM)	Avg C_q	C_q1	C_q2	C_q3
false	100				
true	10	8.24	8.2509	8.2718	8.1954
true	1	11.8	11.8198	11.916	11.6739
true	0.1	14.95	14.9879	14.885	14.9781
true	0.01	18.08	18.0493	18.0696	18.1288
false	0.001				



1: Lib_POOLED_6nM (357 bp) 6.05 nM - Size corrected.

Dilution (1:x)	C_q1	C_q2	C_q3	Avg. C_q	Undiluted Conc
10000	12.4491	12.3975	12.4071	12.42	5.74 nM
100000	15.839	15.9062	15.838	15.86	5.08 nM

2: Lib_POOLED_4nM_Vortex (357 bp) 4.31 nM - Size corrected.

Dilution (1:x)	C_q1	C_q2	C_q3	Avg. C_q	Undiluted Conc
10000	12.9837	12.9836	13.04	13.00	3.80 nM
100000	16.1544	16.2767	16.2629	16.23	3.92 nM

Figure S4.7. The run and lane metrics from the Illumina MiSeqTM sequencing machine of a dust library.

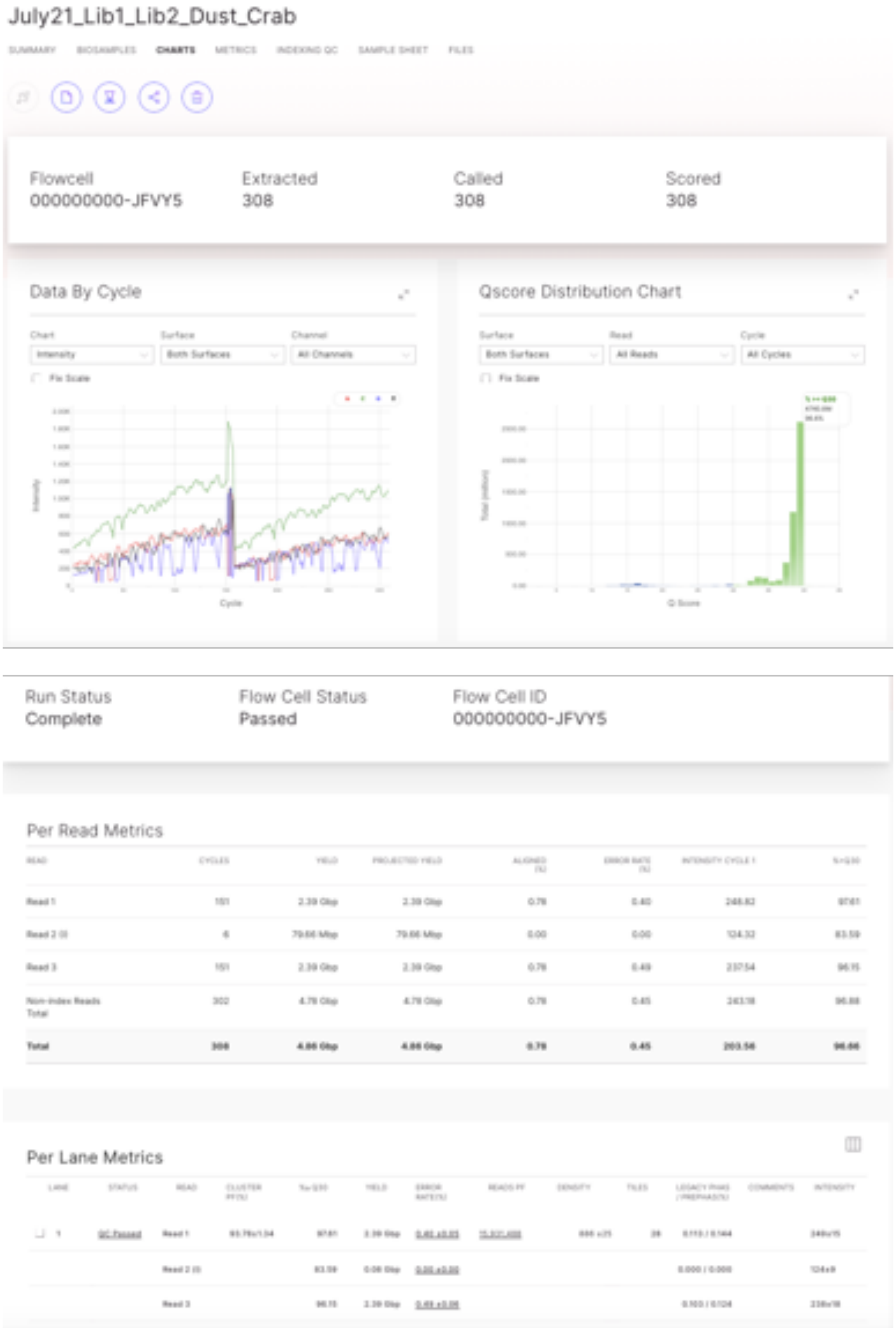


Figure S4.8. Final library quantification (preparing Illumina MiSeq™ Pool) using the NEBio Quant kit of tissue's pool library on the Biomolecular Systems's Magnetic Induction Cycler™ (MIC).

qPCR Library Quantification -- Fri Nov 19 2021

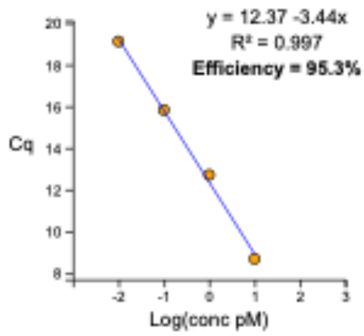
Summary

Standard Curve	Libraries	
Efficiency: 95.3 %	1: 4nM (507 bp)	4.55 nM - Size corrected.
R^2: 0.997	2: 6nM (507 bp)	7.08 nM - Size corrected.
slope: -3.44		

Detailed Input and Results

Standards

Use	Conc (pM)	Avg C_q	C_q1	C_q2	C_q3
false	100				
true	10	8.69	8.7607	8.6428	8.672
true	1	12.72	12.7043	12.725	12.7257
true	0.1	15.84	15.7223	16.0202	15.7632
true	0.01	19.13	19.0394	19.1242	19.2263
false	0.001				



1: 4nM (507 bp) 4.55 nM - Size corrected.

Dilution (1:x)	C_q1	C_q2	C_q3	Avg. C_q	Undiluted Conc
10000	13.278	13.2836	13.2043	13.26	5.53 nM
100000	16.6112	16.575	16.5115	16.57	6.03 nM

2: 6nM (507 bp) 7.08 nM - Size corrected.

Dilution (1:x)	C_q1	C_q2	C_q3	Avg. C_q	Undiluted Conc
10000	12.5604	12.6146	12.5451	12.57	8.73 nM
100000	15.9343	15.8614	15.9704	15.92	9.28 nM

Figure S4.9. The run and lane metrics from the Illumina MiSeq™ sequencing machine of tissue libraries.

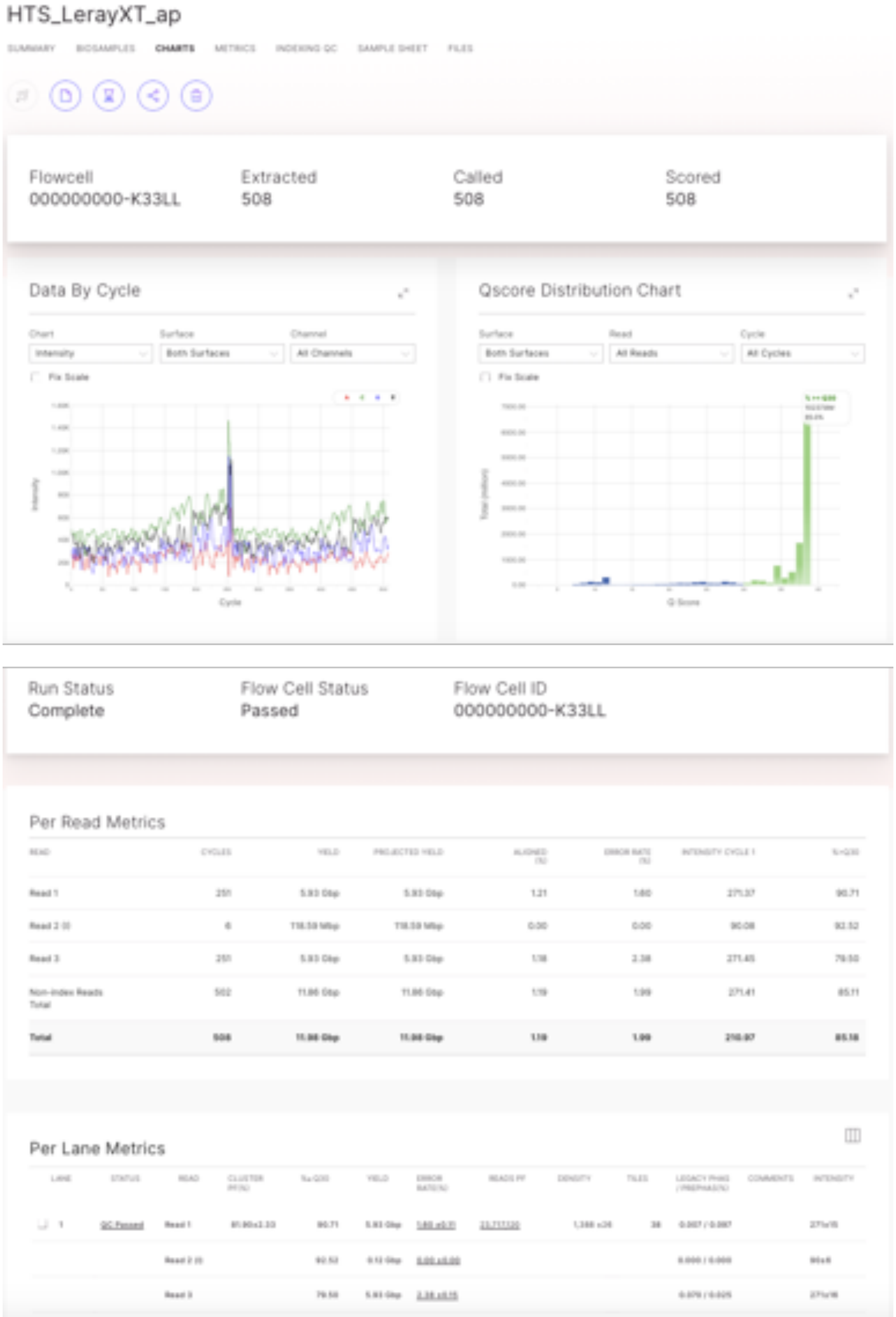


Figure S4.10. The run and lane metrics from the Illumina MiSeq™ sequencing machine of additional 12S reference database.

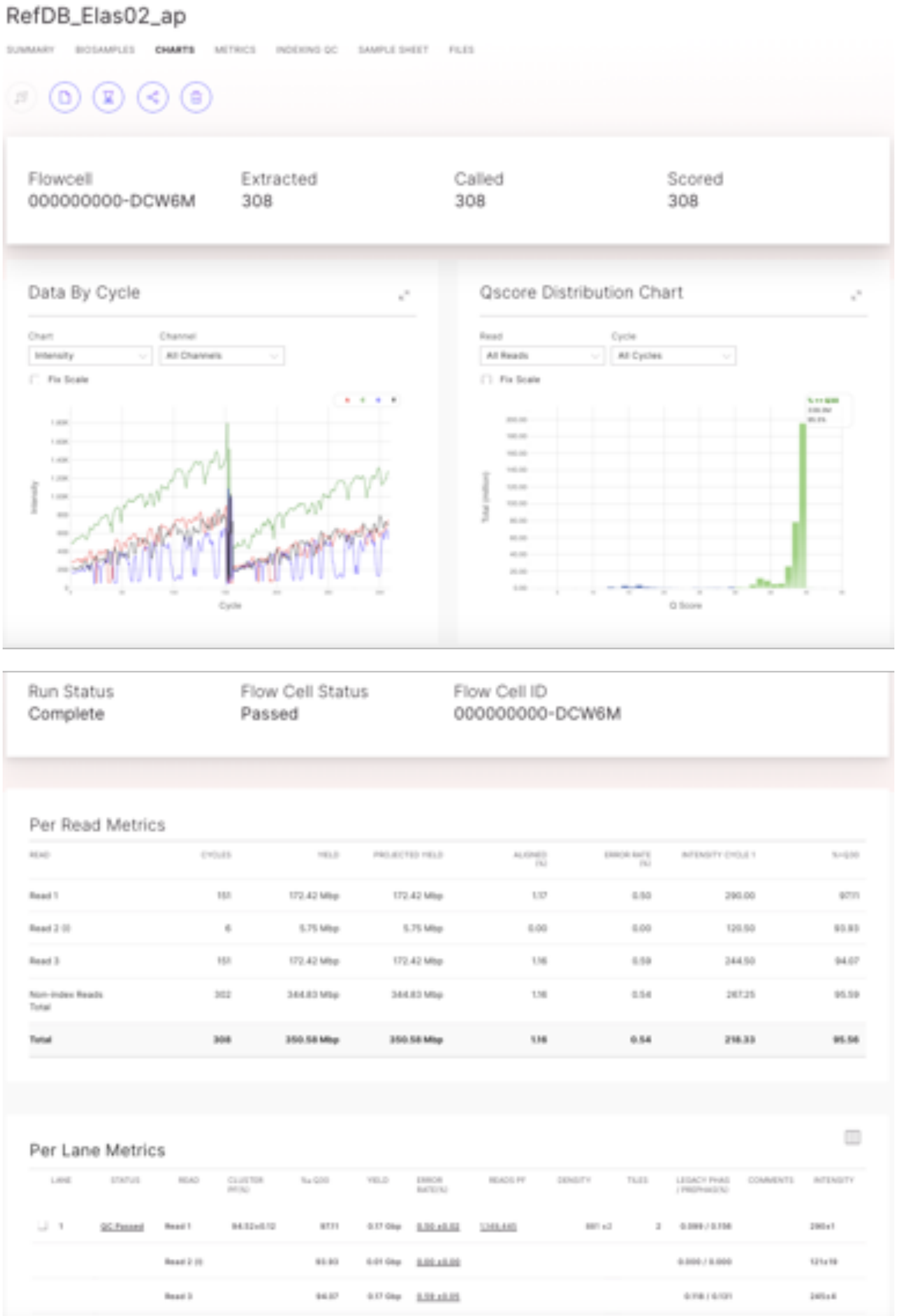


Figure S4.11. General description of sequencing results; read proportions (a) and taxonomy diversity against read numbers (b).

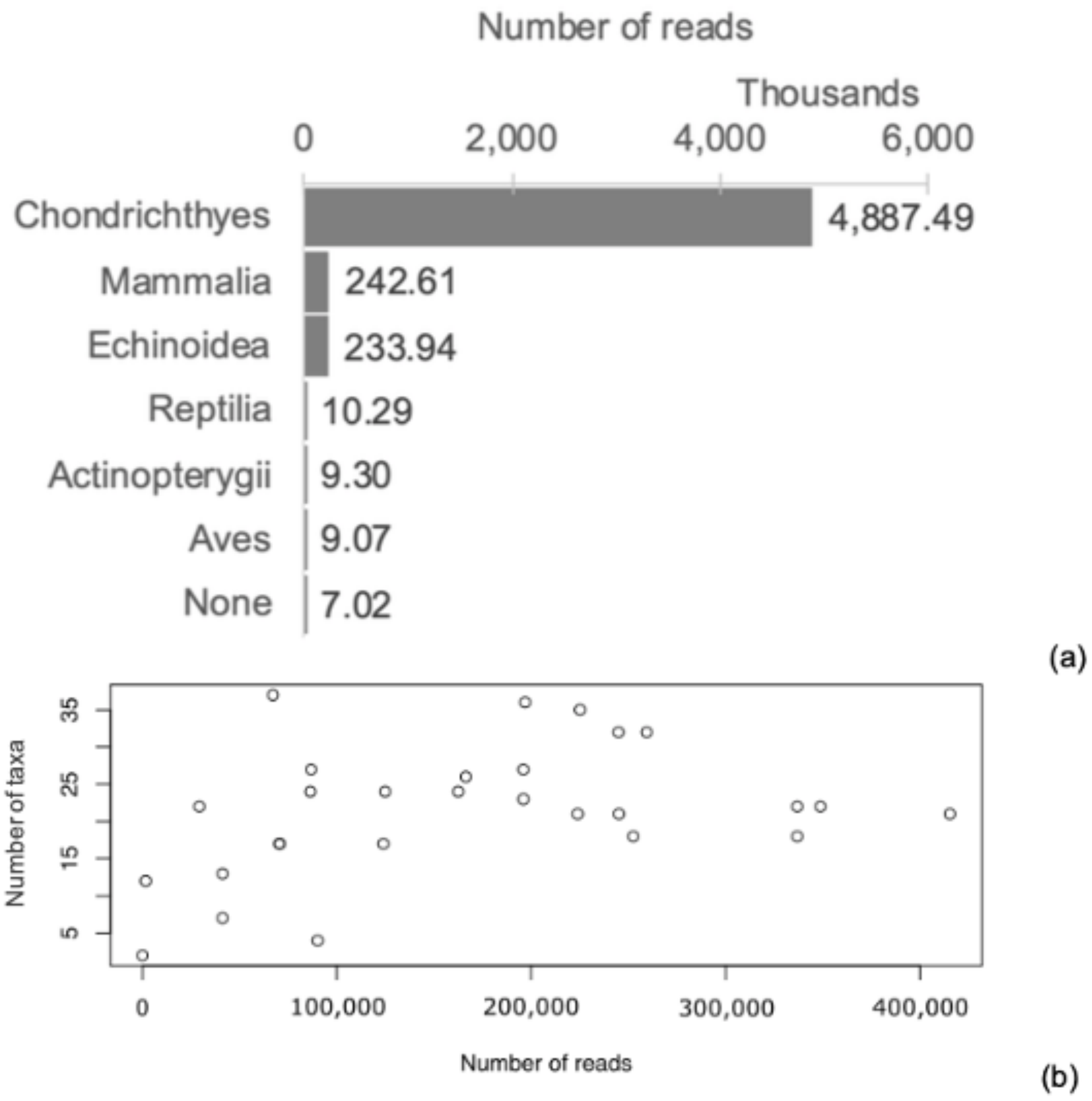


Figure S4.12. Correlation between relative reads abundance (RRA) of species from dust samples and number of individual species from tissue samples for all sampled locations.

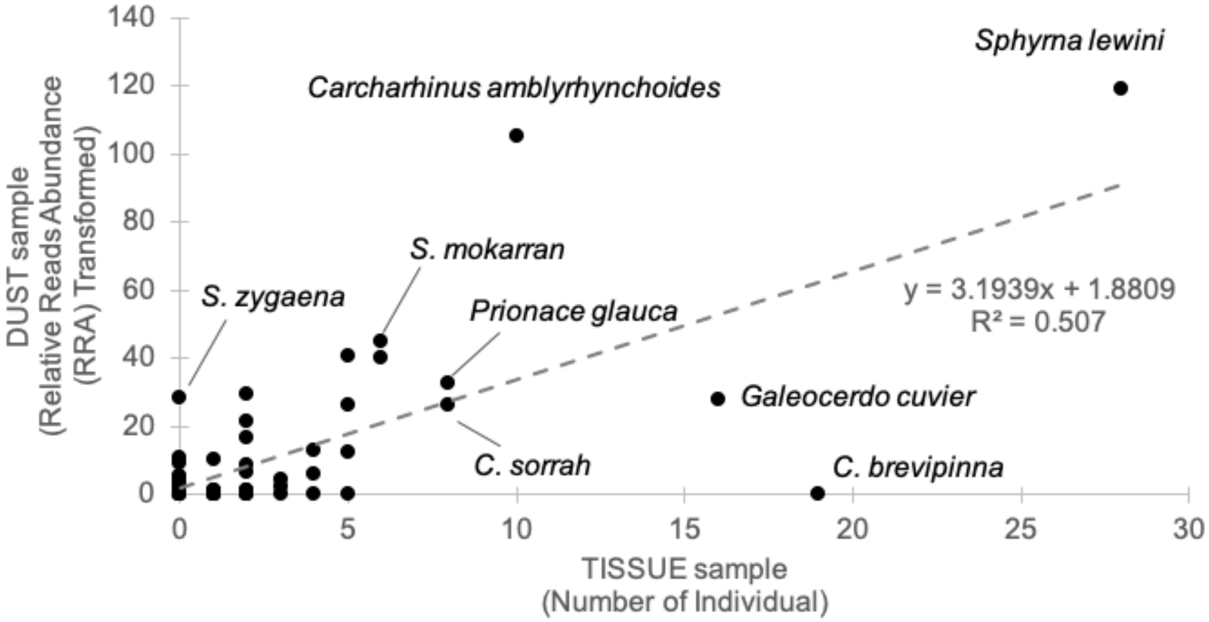


Figure S4.13. Number of raw reads per sampling site used to normalize species composition and to rank the top five species.

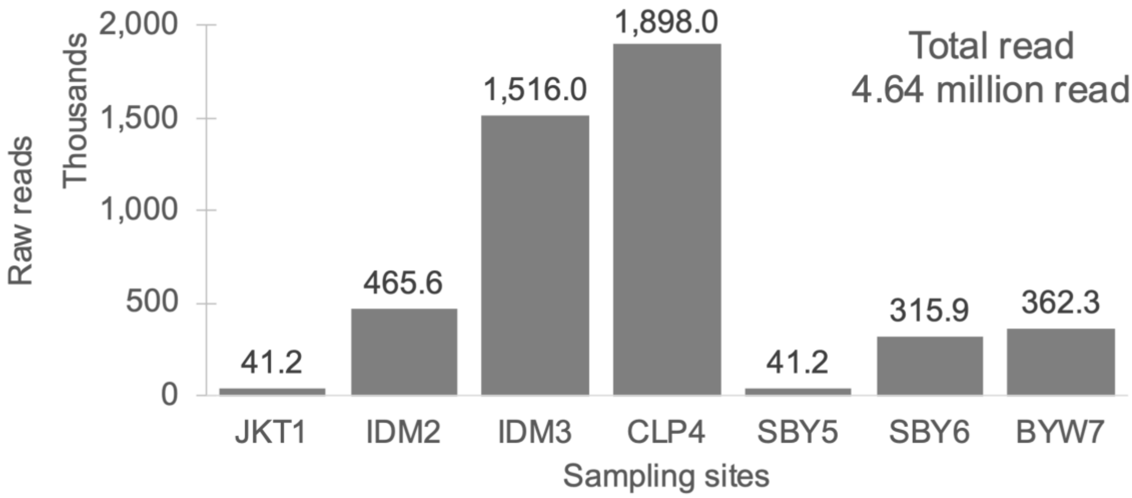


Table S4.1. List of analysed dust samples, including sample code, date of collection, location and notes

No.	Ind ID	Pooled ID	Date	Location	Trader	Association	Notes
1	MB-01	JKT1	9/1/20	Muara Baru	Export hub warehouse	Fin sack	
2	IM-02	IDM2	12/1/20	Indramayu	Processing plant/collector	Fin sack	
3	IM-03	IDM2	12/1/20	Indramayu	Processing plant/collector	Fin sack	
4	IM-04	IDM2	12/1/20	Indramayu	Processing plant/collector	Fin sack	
5	IM-05	IDM2	12/1/20	Indramayu	Processing plant/collector	Fin sack	
6	IM-06	IDM2	12/1/20	Indramayu	Processing plant/collector	Fin sack	
7	IM-07	IDM3	13/1/20	Indramayu	Processing plant/collector	Fin sack	
8	IM-08	IDM3	13/1/20	Indramayu	Processing plant/collector	Fin sack	
9	IM-09	IDM3	13/1/20	Indramayu	Processing plant/collector	Fin sack	
10	IM-10	IDM3	13/1/20	Indramayu	Processing plant/collector	Fin sack	
11	IM-11	IDM3	13/1/20	Indramayu	Processing plant/collector	Cartilage sack	
12	IM-12	IDM3	13/1/20	Indramayu	Processing plant/collector	Cartilage sack	
13	IM-13	IDM3	13/1/20	Indramayu	Processing plant/collector	Cartilage sack	
14	IM-14	IDM3	13/1/20	Indramayu	Processing plant/collector	Cartilage sack	
15	IM-15	IDM3	13/1/20	Indramayu	Processing plant/collector	Skin pile	
16	IM-16	IDM3	13/1/20	Indramayu	Processing plant/collector	Skin pile	
17	IM-17	IDM3	13/1/20	Indramayu	Processing plant/collector	Skin pile	Not enough sample quantity
18	IM-18	IDM3	13/1/20	Indramayu	Processing plant/collector	Skin pile	Not enough sample quantity
19	IM-19	IDM3	13/1/20	Indramayu	Processing plant/collector	Meat boxes	Not enough sample quantity
20	CL-20	CLP4	25/1/20	Cilacap	Processing plant/collector	Fin sack	
21	CL-21	CLP4	25/1/20	Cilacap	Processing plant/collector	Fin dust from saw machine	
22	CL-22	CLP4	25/1/20	Cilacap	Processing plant/collector	Fin dust from saw machine	
23	CL-23	CLP4	25/1/20	Cilacap	Processing plant/collector	Fin dust from saw machine	

No.	Ind ID	Pooled ID	Date	Location	Trader	Association	Notes
24	CL-24	CLP4	25/1/20	Cilacap	Processing plant/collector	Fin dust from saw machine	
25	CL-25	CLP4	26/1/20	Cilacap	Processing plant/collector	Drying places for meat, skin, cartilage and other fishes	
26	CL-26	CLP4	26/1/20	Cilacap	Processing plant/collector	Drying places for meat, skin, cartilage and other fishes	
27	SB-27	SBY5	28/1/20	Surabaya	Authority	Products collection	
28	SB-28	SBY6	29/1/20	Surabaya	Export hub warehouse	Fin sack	
29	SB-29	SBY6	29/1/20	Surabaya	Export hub warehouse	Fin sack	
30	BW-30	BYW7	2/2/20	Banyuwangi	Processing plant/collector	Drying places for skin, cartilage and lower lobe caudal fin in PPP Muncar	
31	BW-31	BYW7	2/2/20	Banyuwangi	Processing plant/collector	Drying places for skin, cartilage and lower lobe caudal fin in PPP Muncar	

Notes: Processing plants (PP), export hubs (EH) and an inspector station (AU)

Table S4.2. List of analysed tissue samples, including sample code, date of collection, location, type of product and species identification

No	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
1	MB-50	9/1/20	Muara Baru	JKT1	EH	Processed	Dried fin	*Isurus oxyrinchus*	CITES
2	MB-51	9/1/20	Muara Baru	JKT1	EH	Processed	Dried fin	*Lamna nasus*	CITES
3	MB-52	9/1/20	Muara Baru	JKT1	EH	Processed	Dried fin	*Isurus paucus*	CITES
4	MB-53	9/1/20	Muara Baru	JKT1	EH	Processed	Dried fin	*Carcharhinus longimanus*	CITES
5	MB-54	9/1/20	Muara Baru	JKT1	EH	Processed	Dried fin	*Alopias superciliosus*	CITES
6	IM-111	12/1/20	Indramayu	IDM2	PP	Processed	Dried fin	Unidentified	
7	IM-112	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Sphyrna lewini*	CITES
8	IM-113	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Sphyrna mokarran*	CITES
9	IM-114	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Carcharhinus brevipinna*	CITES
10	IM-115	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Sphyrna lewini*	CITES
11	IM-116	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus sorrah*	CITES
12	IM-117	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus sorrah*	CITES
13	IM-118	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Hemigaleus australiensis*	Non-CITES
14	IM-119	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus macloti*	CITES
15	IM-120	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus amblyrhynchoides*	CITES
16	IM-121	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Sphyrna lewini*	CITES
17	IM-122	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Sphyrna lewini*	CITES
18	IM-123	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Carcharhinus brevipinna*	CITES
19	IM-124	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Carcharhinus amblyrhynchoides*	CITES
20	IM-125	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Sphyrna lewini*	CITES
21	IM-126	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Sphyrna lewini*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
22	IM-127	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus sorrah*	CITES
23	IM-128	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus sorrah*	CITES
24	IM-129	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Carcharhinus amblyrhynchoides*	CITES
25	IM-130	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Carcharhinus amblyrhynchoides*	CITES
26	IM-131	12/1/20	Indramayu	IDM2	PP	Fresh	Finless	*Carcharhinus amblyrhynchoides*	CITES
27	IM-132	12/1/20	Indramayu	IDM2	PP	Fresh	Whole	*Hemigaleus australiensis*	Non-CITES
28	IM-177	13/1/20	Indramayu	IDM3	PP	Fresh	Finless	*Rhynchobatus laevis*	CITES
29	IM-178	13/1/20	Indramayu	IDM3	PP	Fresh	Whole	*Galeocerdo cuvier*	Non-CITES
30	IM-179	13/1/20	Indramayu	IDM3	PP	Fresh	Trunk	*Stegostoma fasciatum*	Non-CITES
31	IM-180	13/1/20	Indramayu	IDM3	PP	Fresh	Trunk	*Stegostoma fasciatum*	Non-CITES
32	IM-181	13/1/20	Indramayu	IDM3	PP	Fresh	Trunk	*Stegostoma fasciatum*	Non-CITES
33	IM-182	13/1/20	Indramayu	IDM3	PP	Fresh	Finless	*Carcharhinus longimanus*	CITES
34	IM-183	13/1/20	Indramayu	IDM3	PP	Fresh	Whole	*Carcharhinus amblyrhynchoides*	CITES
35	IM-184	13/1/20	Indramayu	IDM3	PP	Fresh	Trunk	*Sphyrna lewini*	CITES
36	IM-185	13/1/20	Indramayu	IDM3	PP	Fresh	Whole	*Carcharhinus sorrah*	CITES
37	IM-186	13/1/20	Indramayu	IDM3	PP	Fresh	Trunk	*Sphyrna lewini*	CITES
38	IM-187	13/1/20	Indramayu	IDM3	PP	Fresh	Trunk	*Sphyrna lewini*	CITES
39	IM-188	14/1/20	Indramayu	IDM3	PP	Fresh	Whole	*Carcharhinus sorrah*	CITES
40	IM-189	14/1/20	Indramayu	IDM3	PP	Fresh	Whole	*Rhynchobatus springeri*	CITES
41	IM-190	14/1/20	Indramayu	IDM3	PP	Fresh	Whole	*Hemigaleus australiensis*	Non-CITES
42	IM-191	13/1/20	Indramayu	IDM3	PP	Processed	Whole Salted	*Chiloscyllium punctatum*	Non-CITES
43	IM-192	13/1/20	Indramayu	IDM3	PP	Processed	Whole Salted	*Rhizoprionodon taylori*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
44	IM-193	13/1/20	Indramayu	IDM3	PP	Processed	Cartillage	Unidentified	
45	IM-194	13/1/20	Indramayu	IDM3	PP	Processed	Cartillage	*Sphyrna lewini*	CITES
46	IM-195	13/1/20	Indramayu	IDM3	PP	Processed	Dried skin	*Stegostoma fasciatum*	Non-CITES
47	IM-196	13/1/20	Indramayu	IDM3	PP	Processed	Dried skin	*Glaucostegus typus*	CITES
48	IM-197	13/1/20	Indramayu	IDM3	PP	Processed	Dried skin	*Sphyrna mokarran*	CITES
49	CL-338	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Isurus paucus*	CITES
50	CL-339	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Isurus paucus*	CITES
51	CL-340	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Alopias pelagicus*	CITES
52	CL-341	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Alopias pelagicus*	CITES
53	CL-341X	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus longimanus*	CITES
54	CL-342	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus longimanus*	CITES
55	CL-343	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Isurus oxyrinchus*	CITES
56	CL-344	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Isurus oxyrinchus*	CITES
57	CL-345	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Alopias superciliosus*	CITES
58	CL-346	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Alopias superciliosus*	CITES
59	CL-347	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus brevipinna*	CITES
60	CL-348	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus brachyurus*	CITES
61	CL-349	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus brachyurus*	CITES
62	CL-350	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus leucas*	CITES
63	CL-351	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus plumbeus*	CITES
64	CL-352	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus leucas*	CITES
65	CL-353	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus leucas*	CITES
66	CL-354	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
67	CL-355	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Prionace glauca*	CITES
68	CL-356	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Prionace glauca*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
69	CL-357	25/1/20	Cilacap	CPL4	PP	Processed	Cartillage	*Alopias superciliosus*	CITES
70	CL-358	25/1/20	Cilacap	CPL4	PP	Processed	Cartillage	*Carcharhinus amblyrhynchoides*	CITES
71	CL-359	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Carcharhinus brevipinna*	CITES
72	CL-360	25/1/20	Cilacap	CPL4	PP	Processed	Dried fin	*Urogymnus granulatus*	Non-CITES
73	CL-363	26/1/20	Cilacap	CPL4	PP	Fresh	Whole	*Galeocerdo cuvier*	Non-CITES
74	CL-364	26/1/20	Cilacap	CPL4	PP	Processed	Dried skin	*Sphyrna mokarran*	CITES
75	CL-365	26/1/20	Cilacap	CPL4	PP	Processed	Dried skin	*Carcharhinus brevipinna*	CITES
76	CL-366	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Alopias superciliosus*	CITES
77	CL-367	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Sphyrna mokarran*	CITES
78	CL-368	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Pateobatis fai*	Non-CITES
79	CL-369	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Hemigaleus australiensis*	Non-CITES
80	CL-370	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Mobula birostris*	CITES
81	CL-371	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Rhinobatos penggali*	CITES
82	CL-372	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Carcharhinus brevipinna*	CITES
83	CL-373	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Rhinobatos penggali*	CITES
84	CL-374	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Carcharhinus sorrah*	CITES
85	CL-375	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Rhinobatos penggali*	CITES
86	CL-376	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Carcharhinus amblyrhynchoides*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
87	CL-377	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Carcharhinus falciformis*	CITES
88	CL-378	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Himantura uarnak*	Non-CITES
89	CL-380	26/1/20	Cilacap	CPL4	PP	Processed	Salted meat	*Pateobatis fai*	Non-CITES
90	SB-381	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus sorrah*	CITES
91	SB-382	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Rhynchobatus springeri*	CITES
92	SB-383	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Rhina ancylostoma*	CITES
93	SB-384	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Isurus oxyrinchus*	CITES
94	SB-385	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus obscurus*	CITES
95	SB-386	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus amblyrhynchoides*	CITES
96	SB-387	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus leucas*	CITES
97	SB-388	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Triaenodon obesus*	CITES
98	SB-389	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus obscurus*	CITES
99	SB-391	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus albimarginatus*	CITES
100	SB-392	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage	*Prionace glauca*	CITES
101	SB-393	28/1/20	Surabaya	SBY5	AU	Processed	Dried skin	*Carcharhinus dussumieri*	CITES
102	SB-394	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin unskin	*Carcharhinus macloti*	CITES
103	SB-395	28/1/20	Surabaya	SBY5	AU	Processed	Oil	Unidentified	
104	SB-396	28/1/20	Surabaya	SBY5	AU	Processed	Oil	Unidentified	
105	SB-397	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage powder	*Mobula tarapacana*	CITES
106	SB-398	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage fin	*Carcharhinus brevipinna*	CITES
107	SB-399	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin unskin	*Prionace glauca*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
108	SB-400	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin unskin	*Prionace glauca*	CITES
109	SB-401	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin hissit	*Sphyrna lewini*	CITES
110	SB-402	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin unskin	*Carcharhinus dussumieri*	CITES
111	SB-403	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage fin	*Mustelus manazo*	Non-CITES
112	SB-404	28/1/20	Surabaya	SBY5	AU	Processed	Dried skin	*Carcharhinus leucas*	CITES
113	SB-405	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin unskin	*Mustelus manazo*	Non-CITES
114	SB-406	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage	*Prionace glauca*	CITES
115	SB-407	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage powder	Unidentified	
116	SB-408	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage powder	Unidentified	
117	SB-409	28/1/20	Surabaya	SBY5	AU	Processed	Cartillage powder	Unidentified	
118	SB-410	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Prionace glauca*	CITES
119	SB-411	28/1/20	Surabaya	SBY5	AU	Processed	Dried fin	*Carcharhinus longimanus*	CITES
120	SB-412	28/1/20	Surabaya	SBY5	AU	Processed	Gill racker	*Mobula birostris*	CITES
121	SB-418	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Sphyrna mokarran*	CITES
122	SB-419	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Sphyrna lewini*	CITES
123	SB-420	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Sphyrna mokarran*	CITES
124	SB-421	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Isurus oxyrinchus*	CITES
125	SB-422	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Glaucostegus typus*	CITES
126	SB-423	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Rhina ancylostoma*	CITES
127	SB-424	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Rhynchobatus australiae*	CITES
128	SB-425	29/1/20	Surabaya	SBY6	EH	Processed	Dried fin	*Rhynchobatus springeri*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
129	BW-432	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
130	BW-433	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
131	BW-434	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
132	BW-435	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
133	BW-436	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
134	BW-437	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
135	BW-438	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Galeocerdo cuvier*	Non-CITES
136	BW-439	2/2/20	Banyuwangi	BYW7	PP	Processed	Teeth	*Galeocerdo cuvier*	Non-CITES
137	BW-440	2/2/20	Banyuwangi	BYW7	PP	Processed	Cartillage	Unidentified	
138	BW-441	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried skin	*Galeocerdo cuvier*	Non-CITES
139	BW-442	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Carcharhinus amblyrhynchoides*	CITES
140	BW-443	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Sphyrna lewini*	CITES
141	BW-444	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Carcharhinus brevipinna*	CITES
142	BW-445	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Sphyrna lewini*	CITES
143	BW-446	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Sphyrna lewini*	CITES
144	BW-447	2/2/20	Banyuwangi	BYW7	PP	Processed	Dried fin	*Sphyrna lewini*	CITES
145	BW-448	2/2/20	Banyuwangi	BYW7	PP	Processed	Gill racker	*Mobula mobular*	CITES
146	BW-449	2/2/20	Banyuwangi	BYW7	PP	Processed	Gill racker	*Mobula mobular*	CITES
147	BW-450	2/2/20	Banyuwangi	BYW7	PP	Processed	Gill racker	*Mobula mobular*	CITES
148	BW-451	2/2/20	Banyuwangi	BYW7	PP	Processed	Gill racker	*Mobula mobular*	CITES
149	BW-452	2/2/20	Banyuwangi	BYW7	PP	Processed	Salted meat	*Carcharhinus melanopterus*	CITES
150	BW-452X	2/2/20	Banyuwangi	BYW7	PP	Processed	Salted meat	*Carcharhinus melanopterus*	CITES
151	BW-453	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Prionace glauca*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
152	BW-454	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Galeocerdo cuvier*	Non-CITES
153	BW-455	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Galeocerdo cuvier*	Non-CITES
154	BW-456	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Galeocerdo cuvier*	Non-CITES
155	BW-457	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Carcharhinus falciformis*	CITES
156	BW-458	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Carcharhinus falciformis*	CITES
157	BW-459	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Sphyrna lewini*	CITES
158	BW-460	2/2/20	Banyuwangi	BYW7	PP	Fresh	Fin	*Carcharhinus brevipinna*	CITES
159	BW-461	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
160	BW-462	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
161	BW-463	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
162	BW-464	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
163	BW-465	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Galeocerdo cuvier*	Non-CITES
164	BW-466	3/2/20	Banyuwangi	BYW7	PP	Fresh	Finless	*Carcharhinus falciformis*	CITES
165	BW-467	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
166	BW-468	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
167	BW-469	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
168	BW-470	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
169	BW-471	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
170	BW-472	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
171	BW-473	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
172	BW-474	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus falciformis*	CITES
173	BW-475	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
174	BW-476	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
175	BW-477	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
176	BW-478	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus falciformis*	CITES

No.	ID	Date	Location	Dust Pooled ID Location	Type of Location	Type of Product	Part	Species Identification	CITES Status
177	BW-479	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
178	BW-480	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Carcharhinus brevipinna*	CITES
179	BW-481	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
180	BW-482	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
181	BW-483	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
182	BW-484	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES
183	BW-485	3/2/20	Banyuwangi	BYW7	PP	Fresh	Whole	*Sphyrna lewini*	CITES

Notes: Processing plants (PP), export hubs (EH) and an inspector station (AU)

Table S4.3. List of species integrated in the curated reference database and the respective number of individual sequences included per species

No.	Family Name	Scientific Name	Number of Sequences
1	Carcharhinidae	*Carcharhinus amblyrhynchoides*	5
2	Carcharhinidae	*Carcharhinus brevipinna*	4
3	Carcharhinidae	*Carcharhinus falciformis*	3
4	Carcharhinidae	*Carcharhinus leucas*	2
5	Carcharhinidae	*Carcharhinus longimanus*	2
6	Carcharhinidae	*Carcharhinus obscurus*	2
7	Carcharhinidae	*Carcharhinus sorrah*	3
8	Carcharhinidae	*Galeocerdo cuvier*	2
9	Carcharhinidae	*Prionace glauca*	2
10	Carcharhinidae	*Rhizoprionodon oligolinx*	2
11	Carcharhinidae	*Carcharhinus albimarginatus*	1
12	Carcharhinidae	*Carcharhinus obscurus*	2
13	Carcharhinidae	*Triaenodon obesus*	1
14	Alopiidae	*Alopias pelagicus*	2
15	Alopiidae	*Isurus oxyrinchus*	2
16	Alopiidae	*Isurus paucus*	2
17	Alopiidae	*Lamna nasus*	1
18	Sphyrnidae	*Sphyrna lewini*	5
19	Sphyrnidae	*Sphyrna mokarran*	3
20	Sphyrnidae	*Eusphyra blochii*	1
21	Hemigaleidae	*Hemigaleus australiensis*	2
22	Hemigaleidae	*Hemipristis elongata*	1
23	Hemiscylliidae	*Chiloscyllium indicum*	1
24	Hemiscylliidae	*Chiloscyllium punctatum*	2
25	Hemiscylliidae	*Chiloscyllium plagiosum*	3
26	Squalidae	*Squalus hemipinnis*	1
27	Pseudocarchariidae	*Pseudocarcharias kamoharai*	1
28	Stegostomatidae	*Stegostoma fasciatum*	2
29	Triakidae	*Mustelus manazo*	1
30	Dasyatidae	*Himantura gerrardi*	1
31	Dasyatidae	*Neotrygon orientalis*	2
32	Dasyatidae	*Telatrygon zugei*	2
33	Dasyatidae	*Hemitrygon bennettii*	2
34	Dasyatidae	*Himantura leoparda*	4
35	Dasyatidae	*Taeniura lymma*	1
36	Myliobatidae	*Mobula tarapacana*	1
37	Myliobatidae	*Mobula birostris*	1

No.	Family Name	Scientific Name	Number of Sequences
38	Myliobatidae	*Mobula mobular*	4
39	Rhynchobatidae	*Rhynchobatus australiae*	2
40	Rhynchobatidae	*Rhynchobatus springeri*	2
41	Rhynchobatidae	*Rhynchobatus laevis*	2
42	Pristidae	*Anoxypristis cuspidata*	2
43	Rhinidae	*Rhina ancylostoma*	2
44	Rhinobatidae	*Glaucostegus typus*	2
45	Gymnuridae	*Gymnura poecilura*	3
		Total	**94**

Table S4.4. Filtering steps removing all MOTUs/reads originating from sequencing errors or contamination and the respective number of reads retrieved at each stage

Filtering Steps	Total
Total Reads	**5,580,616**
After removing reads from the blanks and control	5,098,807
After removing all non-elasmobranch reads	4,640,239

Table S4.5. List of shark species sequenced from dust sample and tissue sample

Family Name	Scientific Name	English Name	Indonesian Name	CITES Status	Dust detection	Tissue detection	NCBI Accession Code
Carcharhinidae	*Prionace glauca*	Blue shark	Hiu selendang	CITES	X	X	XXX
Carcharhinidae	*Carcharhinus falciformis*	Silky shark	Hiu sutra	CITES	X	X	
Carcharhinidae	*Carcharhinus albimarginatus*	Silvertip shark	Hiu silvertip	CITES	X	X	
Carcharhinidae	*Carcharhinus brachyurus*	Copper shark	Hiu lanjaman	CITES		X	
Carcharhinidae	*Carcharhinus brevipinna*	Spinner shark	Hiu plen	CITES		X	
Carcharhinidae	*Carcharhinus longimanus*	Oceanic whitetip shark	Hiu koboi	CITES	X	X	
Carcharhinidae	*Carcharhinus obscurus*	Dusky shark	Hiu lanjaman	CITES		X	
Carcharhinidae	*Carcharhinus plumbeus*	Sandbar shark	Hiu teteri	CITES	X	X	
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful shark	Hiu lanjaman	CITES	X	X	
Carcharhinidae	*Carcharhinus melanopterus*	Blacktip reef shark	Hiu mada	CITES	X	X	
Carcharhinidae	*Carcharhinus sorrah*	Spot-tail shark	Hiu lanjaman	CITES	X	X	
Carcharhinidae	*Carcharhinus leucas*	Bull shark	Hiu buas	CITES	X	X	
Carcharhinidae	*Carcharhinus amboinensis*	Java shark	Hiu lanjaman	CITES	X		
Carcharhinidae	*Carcharhinus macloti*	Hardnose shark	Hiu aron	CITES	X	X	
Carcharhinidae	*Triaenodon obesus*	Whitetip reef shark	Hiu bokem	CITES		X	
Carcharhinidae	*Carcharhinus dussumieri*	Whitecheek shark	Hiu lanjaman	CITES		X	
Carcharhinidae	*Carcharhinus tjutjot*	Indonesian whaler shark	Hiu lanjaman	CITES	X		

Family Name	Scientific Name	English Name	Indonesian Name	CITES Status	Dust detection	Tissue detection	NCBI Accession Code
Carcharhinidae	*Glyphis glyphis*	Speartooth shark		CITES	X		
Carcharhinidae	*Lamiopsis tephrodes*	Borneo broadfin shark	Hiu bujit	CITES	X		
Carcharhinidae	*Scoliodon macrorhynchos*	Pacific spadenose shark	Hiu kejen	CITES	X		
Carcharhinidae	*Loxodon macrorhinus*	Sliteye shark	Hiu kejen	CITES	X		
Carcharhinidae	*Rhizoprionodon oligolinx*	Grey sharpnose shark	Hiu plen	CITES	X		
Carcharhinidae	*Rhizoprionodon taylori*	Australian sharpnose shark	Hiu plen	CITES		X	
Carcharhinidae	*Galeocerdo cuvier*	Tiger shark	Hiu macan	Non-CITES	X	X	
Sphyrnidae	*Eusphyra blochii*	Winghead shark	Hiu caping	CITES	X		
Sphyrnidae	*Sphyrna mokarran*	Great hammerhead	Hiu caping	CITES	X	X	
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead	Hiu caping	CITES	X	X	
Sphyrnidae	*Sphyrna zygaena*	Smooth hammerhead	Hiu caping	CITES	X		
Alopiidae	*Isurus oxyrinchus*	Shortfin mako shark	Hiu tenggiri	CITES	X	X	
Alopiidae	*Isurus paucus*	Longfin mako shark	Hiu tenggiri	CITES	X	X	
Alopiidae	*Lamna nasus*	Porbeagle shark		CITES		X	
Alopiidae	*Alopias pelagicus*	Pelagic thresher	Hiu monyet	CITES	X	X	
Alopiidae	*Alopias superciliosus*	Bigeye thresher	Hiu monyet	CITES	X	X	
Hemigaleidae	*Hemigaleus australiensis*	Australian weasel shark	Hiu kacang	Non-CITES	X	X	
Hemigaleidae	*Hemigaleus microstoma*	Sicklefin weasel shark	Hiu kacang	Non-CITES	X		

Family Name	Scientific Name	English Name	Indonesian Name	CITES Status	Dust detection	Tissue detection	NCBI Accession Code
Hemigaleidae	*Hemipristis elongata*	Snaggletooth shark	Hiu monas	Non-CITES	X		
Hemiscylliidae	*Chiloscyllium plagiosum*	Whitespotted bamboo	Hiu bongo	Non-CITES	X		
Hemiscylliidae	*Chiloscyllium punctatum*	Brownbanded bamboo	Hiu bongo	Non-CITES	X	X	
Triakidae	*Mustelus griseus*	Spotless smooth-hound	Hiu kacang	Non-CITES	X		
Triakidae	*Mustelus manazo*	Starspotted smooth-hound	Hiu kacang	Non-CITES	X	X	
Odontaspididae	*Carcharias taurus*	Sand tiger shark	Hiu anjing	Non-CITES	X		
Hexanchidae	*Hexanchus griseus*	Bluntnose sixgill shark	Hiu areuy	Non-CITES	X		
Squalidae	*Squalus hemipinnis*	Indonesian shortsnout spurdog	Hiu botol	Non-CITES	X		
Stegostomatidae	*Stegostoma fasciatum*	Zebra shark	Hiu belimbing	Non-CITES	X	X	
Dasyatidae	*Himantura gerrardi*	Whitespotted whipray	Pari bintang	Non-CITES	X		
Dasyatidae	*Himantura leoparda*	Leopard whipray	Pari macan	Non-CITES	X		
Dasyatidae	*Himantura uarnak*	Reticulate whipray	Pari macan	Non-CITES		X	
Dasyatidae	*Pateobatis fai*	Pink whipray	Pari minyak	Non-CITES		X	
Dasyatidae	*Himantura jenkinsii*	Jenkins whipray	Pari duri	Non-CITES	X		
Dasyatidae	*Himantura hortlei*	Hortle's whipray		Non-CITES	X		
Dasyatidae	*Himantura granulata*	Mangrove whipray	Pari sapi	Non-CITES	X		
Dasyatidae	*Urogymnus granulatus*	Mangrove whipray		Non-CITES		X	
Dasyatidae	*Neotrygon kuhlii*	Bluespotted stingray	Pari blentik	Non-CITES	X		

Family Name	Scientific Name	English Name	Indonesian Name	CITES Status	Dust detection	Tissue detection	NCBI Accession Code
Dasyatidae	*Dasyatis thetidis*	Thorntail stingray		Non-CITES	X		
Dasyatidae	*Dasyatis zugei*	Pale-edged stingray	Pari biasa	Non-CITES	X		
Dasyatidae	*Pastinachus atrus*	Cowtail stingray		Non-CITES	X		
Myliobatidae	*Mobula birostris*	Giant oceanic manta ray	Pari kerbau	CITES	X	X	
Myliobatidae	*Mobula tarapacana*	Sicklefin devil ray	Pari lampingan	CITES	X	X	
Myliobatidae	*Mobula thurstoni*	Bentfin devil ray	Pari lampingan	CITES	X		
Myliobatidae	*Mobula mobular*	Giant devil ray	Pari lampingan	CITES	X	X	
Rhynchobatidae	*Rhynchobatus australiae*	Whitespotted guitarfish	Liongbun	CITES	X	X	
Rhynchobatidae	*Rhynchobatus laevis*	Smoothnose wedgefish	Liongbun	CITES	X	X	
Rhynchobatidae	*Rhynchobatus springeri*	Broadnose wedgefish	Liongbun	CITES	X	X	
Rhinidae	*Rhina ancylostoma*	Bowmouth guitarfish	Hiu barong	CITES	X	X	
Rhinobatidae	*Glaucostegus typus*	Giant guitarfish	Pari kekeh	CITES	X	X	
Pristidae	*Anoxypristis cuspidata*	Knifetooth sawfish	Pari gergaji lancip	CITES	X		
Rhinobatidae	*Rhinobatos penggali*	Indonesian shovelnose ray	Pari kekeh	CITES		X	
Gymnuridae	*Gymnura poecilura*	Longtail butterfly ray	Pari kalelawar	Non-CITES	X		
Carcharhinidae	*Carcharhinus* sp.	Requiem sharks		CITES			
Dasyatidae	*Himantura* sp.	Whiprays					
Myliobatidae	*Mobula* sp.	Manta/Devil rays		CITES			
Rhinopteridae	*Rhinoptera* sp.	Cownose rays					

Family Name	Scientific Name	English Name	Indonesian Name	CITES Status	Dust detection	Tissue detection	NCBI Accession Code
Rhynchobatidae	*Rhynchobatus* sp.	Guitarfishes		CITES			
Carcharhinidae		Requiem shark families					
Rhinobatinae		Guitarfish families		CITES			

Table S4.6. The result of PERMANOVA analysis to test for compositional differences between the two types of samples, shark-dust and individual specimen tissues.

Permutation: free
Number of permutations: 999

	df	Sum	MS	F.Model	R^2	Pr(>F)
Type	1	0.7860	0.78600	3.4976	0.22569	0.001
Residuals	12	2.6967	0.22472		0.77431	
Total	13	3.4827	1.00000			

Table S4.7. Ambiguity in species identification

Genus	Species list
11 Carcharhinus haplotypes that could not be unambiguously assigned to one species.	*Carcharhinus amboinensis* and *Carcharhinus obscurus*
	Carcharhinus plumbeus and Carcharhinus albimarginatus
	Carcharhinus amblyrhynchoides and *Carcharhinus sorrah*
	Carcharhinus falciformis, Carcharhinus amblyrhynchoides and *Carcharhinus sorrah*
	Carcharhinus acronotus, Carcharhinus porosus, Carcharhinus amboinensis and *Carcharhinus obscurus*
	Carcharhinus acronotus, Carcharhinus porosus, Carcharhinus obscurus, Carcharhinus amboinensis and *Carcharhinus macloti*
	Carcharhinus plumbeus, Carcharhinus acronotus, Carcharhinus porosus, Carcharhinus amboinensis and *Carcharhinus obscurus*
	Carcharhinus longimanus, Carcharhinus porosus, Carcharhinus obscurus, Carcharhinus amboinensis and *Carcharhinus acronotus*
	Carcharhinus acronotus, Carcharhinus porosus, Carcharhinus obscurus, Carcharhinus amboinensis and *Carcharhinus amblyrhynchoides*
	Carcharhinus plumbeus, Carcharhinus albimarginatus, Carcharhinus porosus, Carcharhinus acronotus and *Carcharhinus amblyrhynchoides*
	Carcharhinus porosus, Carcharhinus amblyrhynchoides, Carcharhinus tjutjot, Carcharhinus amboinensis, Carcharhinus acronotus and *Carcharhinus obscurus*
Some genus *Himantura*	*Himantura leoparda* and *H. uarnak*
Some genus *Mobula*	*Mobula formosana, Mobula japanica* and *Mobula mobular*
	Mobula eregoodootenkee, Mobula kuhlii and *Mobula thurstoni*
Some genus *Rhinoptera*	*Rhinoptera javanica* and *R. steindachneri*
Some genus *Rhynchobatus*	*Rhynchobatus laevis* and *Rhynchobatus australiae*
	Rhynchobatus springeri and *Rhynchobatus djiddensis*
	Rhynchobatus laevis, Rhynchobatus australiae and *Rhynchobatus djiddensis*

Genus	Species list
Some family Carcharhinidae	*Prionace glauca, Carcharhinus acronotus* and *Carcharhinus obscurus*
	Carcharhinus plumbeus, Carcharhinus porosus, Carcharhinus amblyrhynchoides, Glyphis siamensis, Glyphis fowlerae, Glyphis gangeticus, Carcharhinus leucas, Glyphis sp. Pakistan, Carcharhinus albimarginatus, Carcharhinus acronotus and *Carcharhinus obscurus*
	Carcharhinus porosus, Carcharhinus acronotus, Carcharhinus amblyrhynchoides, Carcharhinus tjutjot, Carcharhinus amboinensis, Lamiopsis temminckii and *Carcharhinus obscurus*
	Carcharhinus acronotus and *Prionace glauca*
	Carcharhinus porosus, Carcharhinus acronotus, Carcharhinus amblyrhynchoides, Carcharhinus amboinensis, Lamiopsis temminckii and *Carcharhinus obscurus*
Some subfamily Rhinobatinae	*Glaucostegus formosensis, Rhinobatos schlegelii* and *Rhinobatos hynnicephalus*