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Article

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Highlights

- Indonesia plays major role on landing and export of shark and ray;
- Substantial mismatch volume of landing and export for domestic consumption;
- Mismatch of international trade flow between Indonesia and partner countries;
- Export volume may underestimation due to unreported or illegal trading activities;
- Incorporated socio-economic dimension to develop effective measures is mandatory.

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 $43.6M and $20.9M 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.

Graphical Abstract

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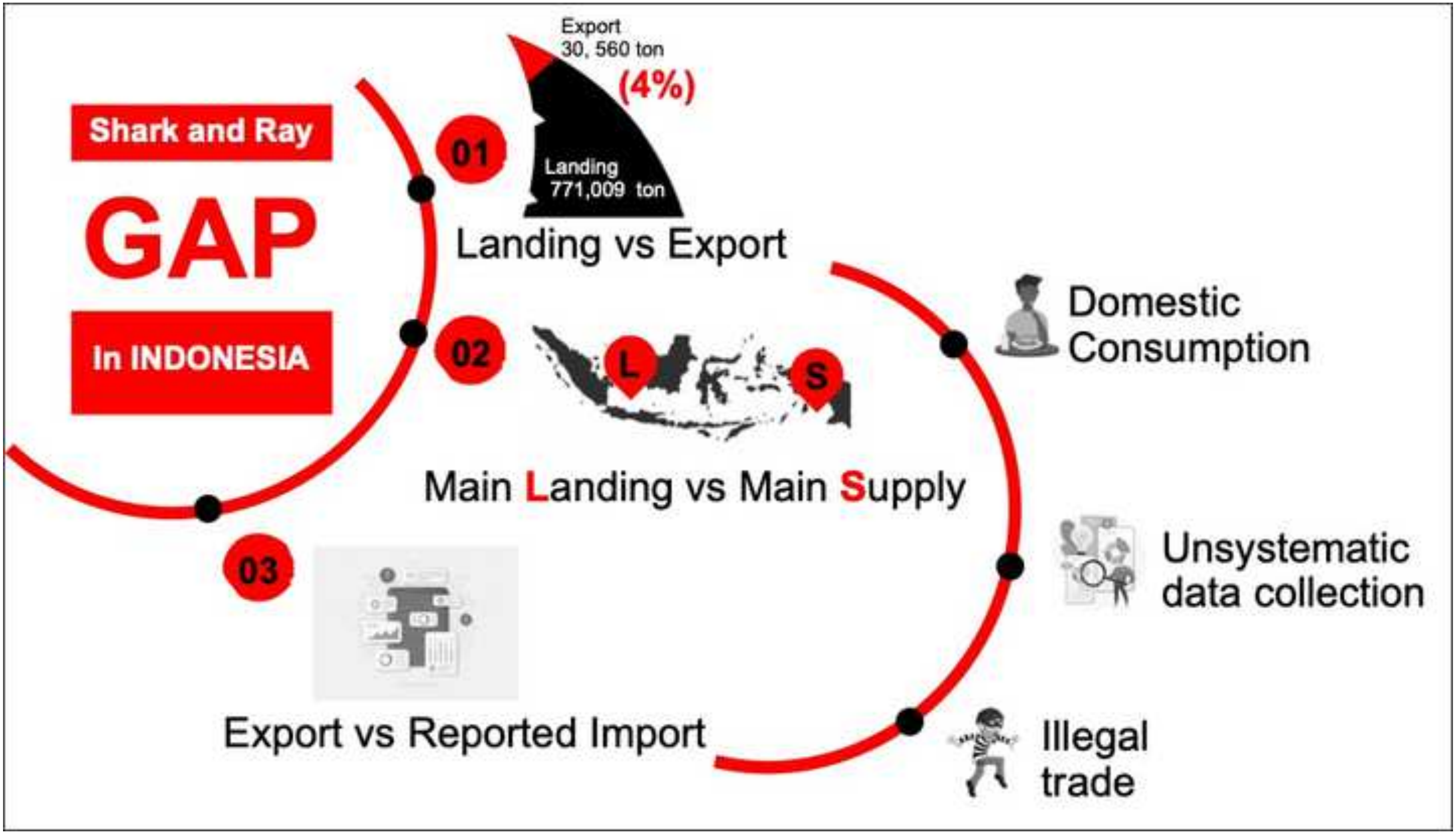

Shark and ray trade in and out of Indonesia: addressing knowledge gaps on the path to sustainability

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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 [1, 2]. Conservative life-histories [3] make elasmobranchs vulnerable to fisheries overexploitation [4, 5], which in turn can destabilise ecosystem structure [6] and ultimately decrease global functional diversity [7]. 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 [1, 8]. 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 [9, 10]. Much of this trade involves poorly reported catches from Eastern and Western Pacific countries, which supply, for instance, global elasmobranch fin markets [11, 12]. 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 1) [13-15].

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 [16-18]. Indonesia is also the fourth most populous country in the world, with many communities traditionally associated with the sea [19]. 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, [20] 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 [20, 21]. Between 2007-2017, Indonesia was the largest reported contributor to global elasmobranch landings, with a mean catch of 110,737 mt per year [22, 23]. 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 [24] and other approaches [25], 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 [22]. However, since 2015, a dramatic increase was observed in the export of meat products in Indonesia [26]. This has been linked to emerging trammel net by-catch, as a consequence of the ban on shrimp trawling [27]. 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 [28]. 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 [29-31]. 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. 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 [32-34]. 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) [17]. Those official statistics were combined with the global capture production database from the UN Food & Agriculture Organisation [23] 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 [35]. The volume of domestic elasmobranch product exchange between source and destination locations was then plotted using the R package “network3D” [36]. To improve clarity, domestic trade was filtered to flows larger than 10 ton.

The elasmobranch import/export data were derived from the FAO Fisheries Statistics [37] and the Agency for Fish Quarantine and Quality Insurance [35] over a seven-year period (2012–2018). This analysis period was selected because the FAO Fishery Commodities and Trade statistical collection [37] 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 [23]. 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 [38]. 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 [39]. Discrepancy between Indonesia and bilateral trade partners were traced using the method detailed by [40] 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 S1.

3. Results

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 [23, 32, 34]. 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).

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 3a). 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 3b). An increase of other rays since 2015 were generally dominated by the families of Gymuridae and Glaucostegidae.

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 ton 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 ton, respectively (Figure 4). In these two major areas, ray landings were substantially greater than shark catches. In those FMAs, tuna longliners, gillnetters and trawlers were the dominant fishing gears [34]. 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.

3.2. Domestic trade statistics

Based on national statistics, in 2018, the export of elasmobranch products was only just over 11.7% (11,867 ton) of landing data (101,707 ton), and only around 4% (30,560 ton) over the whole period between 2012 and 2018 (771,009 ton). 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 5a), with Bali and Papua together accounting for 68.2% of the outflow at 10,587 ton. The Bali province also plays a role as a transit hub prior to subsequent shipping to Jakarta and East Java Provinces (Surabaya) (Figure 5b), 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 Figure S2.

3.3. International trade statistics

Between 2013 and 2018, exported elasmobranch products increased steadily and reached a peak of 8,320 ton in 2017 (Figure 6a). Over 70% of the exported products are still dominated by meat, except in 2016, where the export of fins (878 ton out of 3,002) and cartilages (1,346 ton 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 ton 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 6b) 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.

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 7a). In some cases, Indonesia reported less than what the importing countries declared (e.g. Hong Kong reporting 440.5 ton 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 ton less than what was recorded by Indonesia). Similarly, this phenomenon was also revealed in the meat trade (Figure 7b), with the notable case of Malaysia, which reports nearly 9,000 ton 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 ton) and 47.1% (13,138 ton) of the export volume reported by Indonesia (2,689 ton and 27,871 ton). 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 S3.

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 [20]. 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 [13], 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 [13, 41]. 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 [42-45]. 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 5a). 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 5b), 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 value 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 ton and 13,138 ton respectively. This mismatch amounts to 54.4% of the total 2,689 ton export declared in the fin trade, which is valued at approximately 43.6 million US$ (based on the estimated value of 29,800 US$/ton). Gaps are mostly caused by the fin trade with Singapore (under-reporting) and Hong Kong (over-reporting), by 521 and 440 ton respectively. On the other hand, there was a mismatch of 47.1% of the reported export in the meat trade, a value of approximately 21 million US$ (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 ton). This highlights substantial economic loss due to the mismatch in fin and 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 Table S4). 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 [46, 47]. Similar findings on trade discrepancy between Hong Kong and its partner countries highlighted the importance of comprehensive data recording on elasmobranch fin trade [14]. It also advocates for the authorities to improve their capacity to reduce the risk that illegal products might contribute to such gaps.

Anthropogenic impacts on functional diversity of marine megafauna, their ripple effect on ecosystem structure [6, 48], and greater awareness of the value of marine predators when alive [49] 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 [29, 50-52]. 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 [53-55]. 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 [56]. Other authors also have debated the effectiveness of the Convention's measures [9, 24, 55, 57, 58], 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 compound to set major challenges for the sustainable management of sharks and rays. Due to its failure to incorporate the complex reality of socio-ecological systems, the effectiveness of the CITES framework has been questioned in relation to tackling illegal wildlife trade [29, 58, 59]. For instance, the CITES implementation rarely touches grassroot stakeholders (i.e. fishers), who are the most impacted by the regulation and tend to leave them with uncertainty and misinformation.

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 [60]. 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 "cobra effect" [61] 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 [2]. Current management should be reconsidered to attain a better trade-off of conservation and management measures [62].

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 [63]. 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 [25].

Successful shark and ray conservation measures require sufficient data collection [64]. 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 48 species of elasmobranchs listed in the CITES's Appendices as of 2019. Of these, 30 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) across the country, 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 [28]. Emerging DNA barcoding techniques that are affordable and reliable are pivotal for traceability [46]. All these circumstances determine the intricacies of domestic and international trade flows in Indonesia (Figure 8), whose disentanglement will require multi-disciplinary approaches, solid collaboration and substantial engagement.

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 [65, 66]). 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 [67]; iii) expanding national capabilities in technologies (e.g. DNA testing, [46]) 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 [68]. A typical example is the often touted ‘shark tourism solution’, which only works in certain places and for certain species [55], and is bound to fail without effective community engagement [49]. 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.

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Author contribution

A.P., A.D.M., J.M., J.M., F.A, E.M., and S.M. conceived, designed and coordinated the study; Data Collection and data analyses were conducted by A.P; A.P. wrote the manuscript; all authors read and commented on the manuscript.

Additional Information

Supplementary information

Supplementary Table S1. Shark and ray production and trade data used in this study

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

Supplementary Figure S3. Annual volume of reported export and import by/from Indonesia in 2012-2018 for fin products (a) and meat products (b)

Supplementary Table S4: Elasmobranch product HS codes used in trade, 2008–2018 (UN Comtrade)

Competing Interests: The authors declare that they have no competing interests.

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Figures

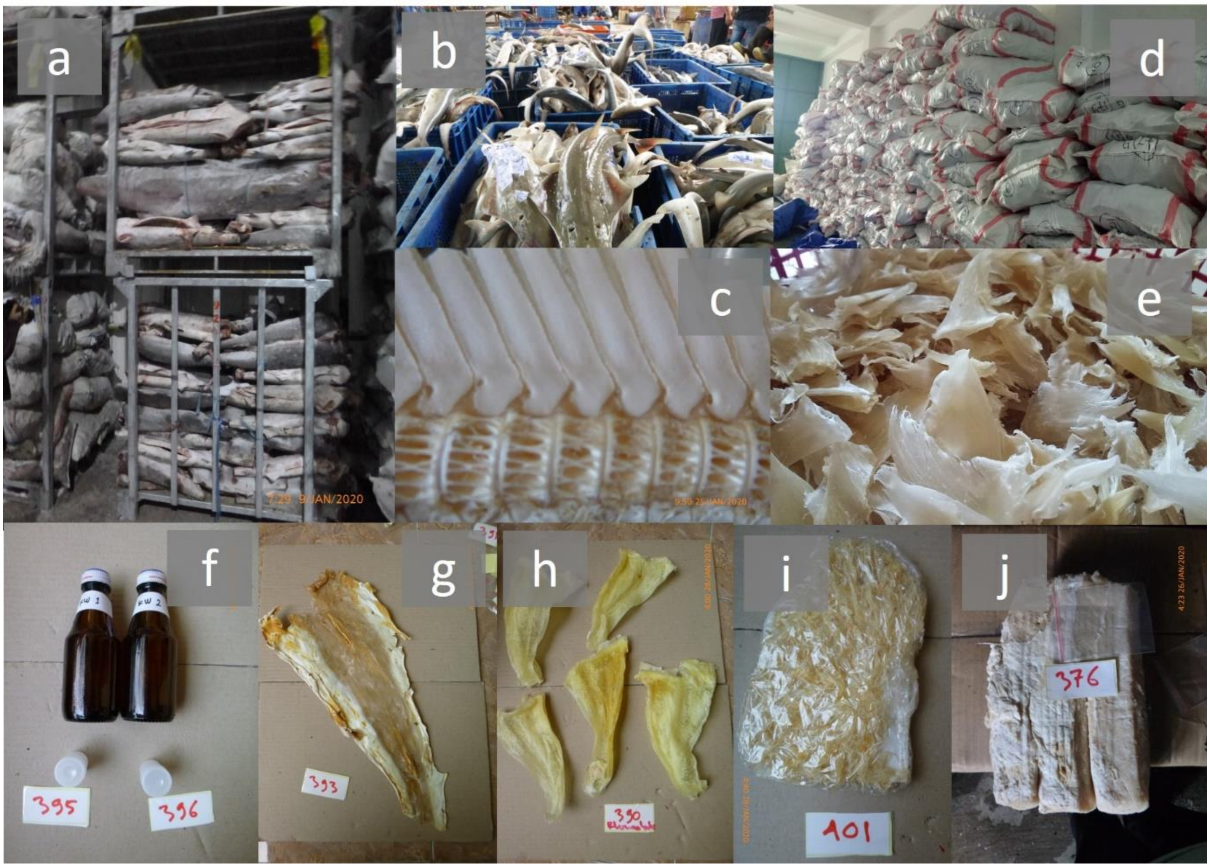

Figure 1. Storage, appearance and diversity (export commodities) of shark products: (a) frozen shark trunks in cold storage, (b) fresh rays landed in Indramayu, (c) ray cartilage, (d) stock pile of controlled species waiting for quota, (e) peeled shark fins, (f) shark oil, (g) peeled shark skin, (h) peeled ray fins, (i) noodle-like “hissit” produced from shark fins, and (j) shark salted meat.

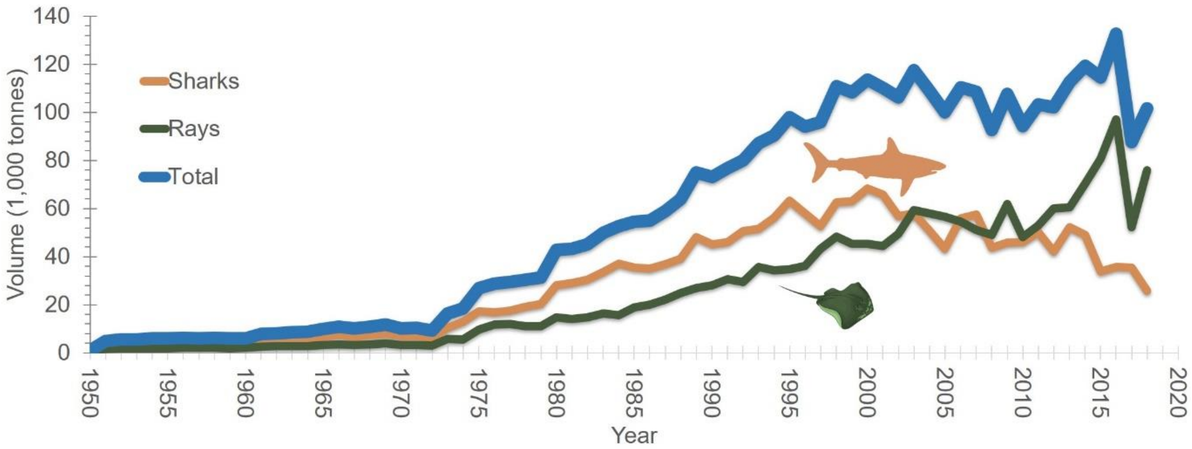

Figure 2. Shark landing in Indonesia 1950-2018. [23, 31, 33]

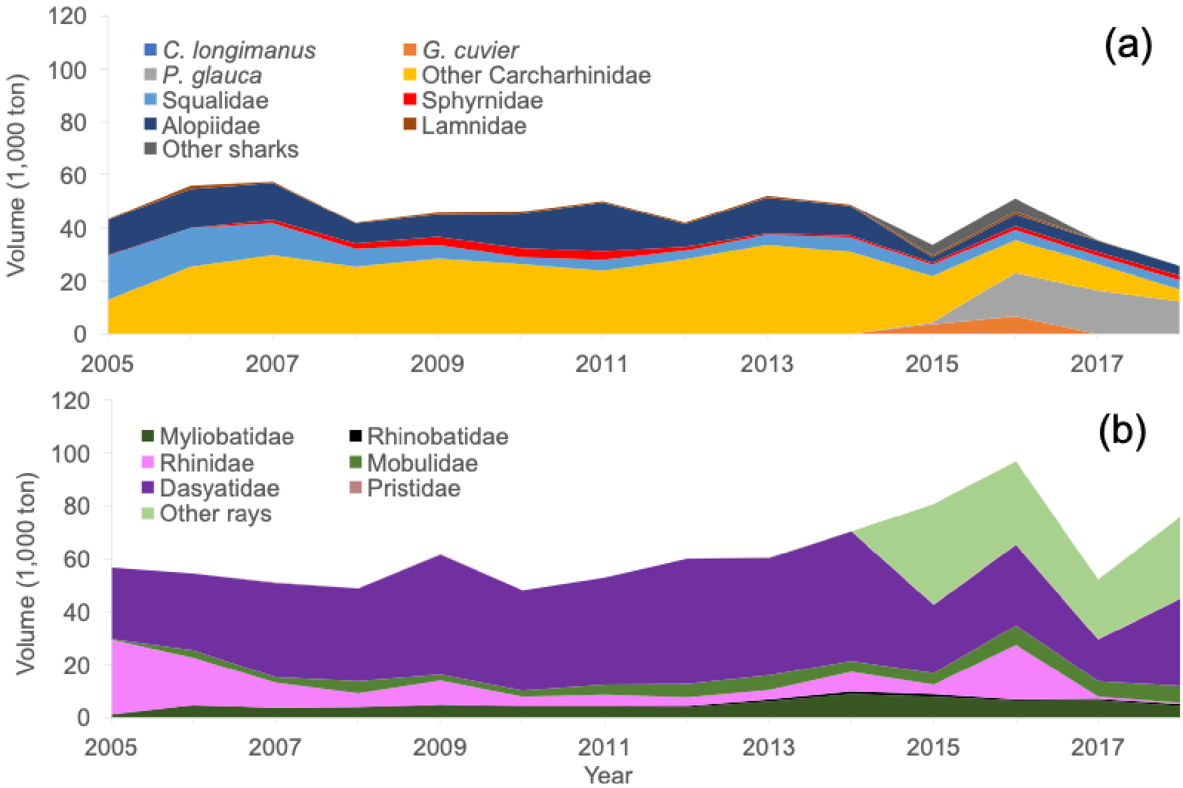

Figure 3. Sharks (a) and ray (b) landing and composition in Indonesia by species group 2005-2018 [23, 31, 33].

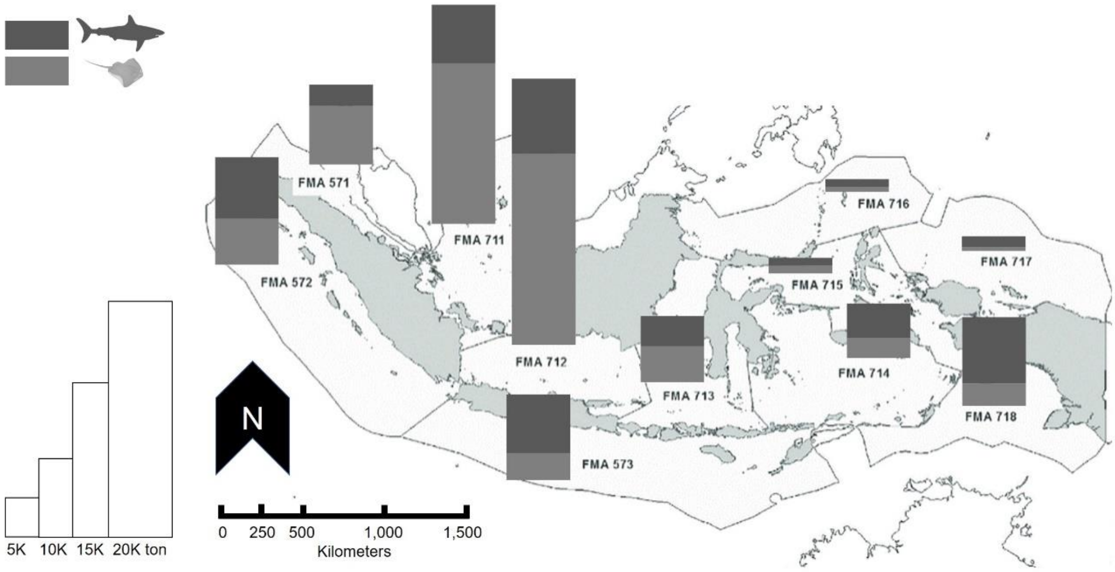

Figure 4. Cumulative volume of shark and ray landing by Fisheries Management Area (FMA) during 2005-2018 [23, 31, 33].

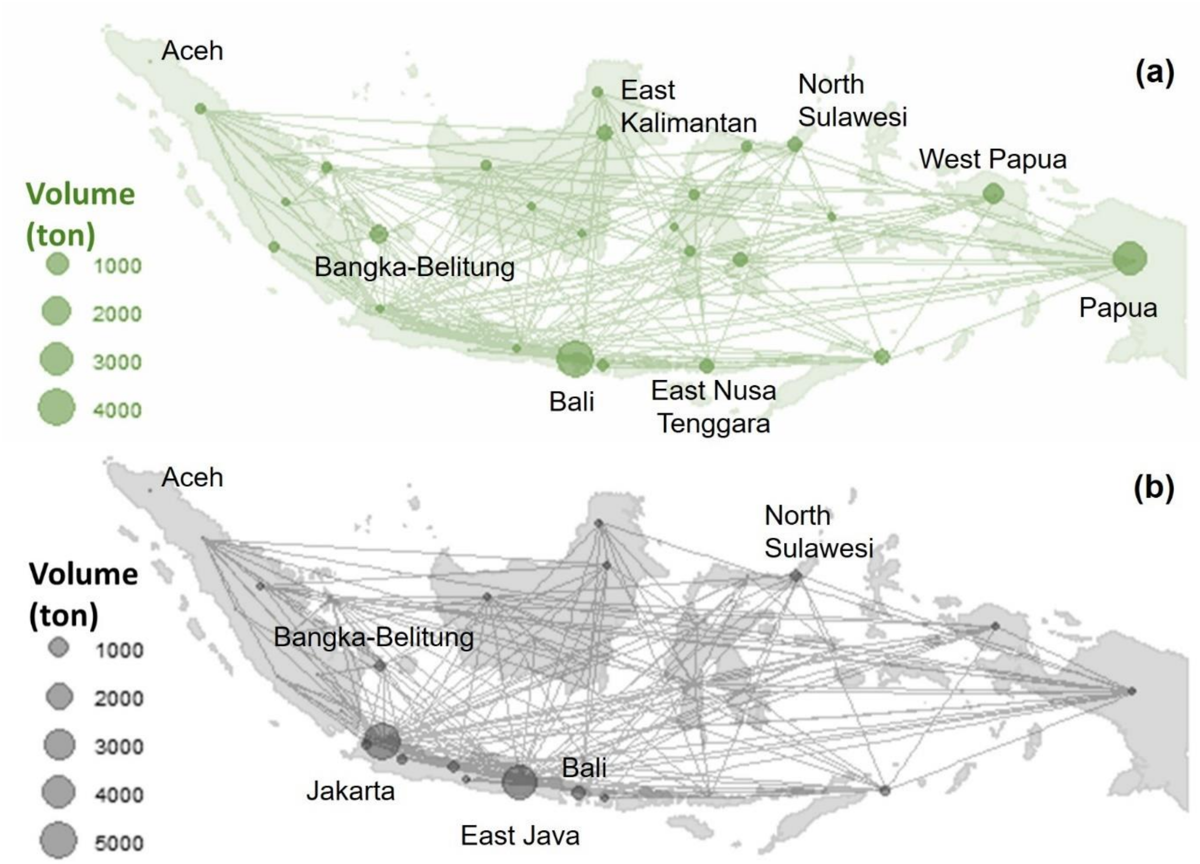

Figure 5. Domestic trade network of fin and meat products across the Indonesian region within 2014-2018 (ton) by source (a) and destination provinces (b); provinces with label indicate significant contribution. [34]

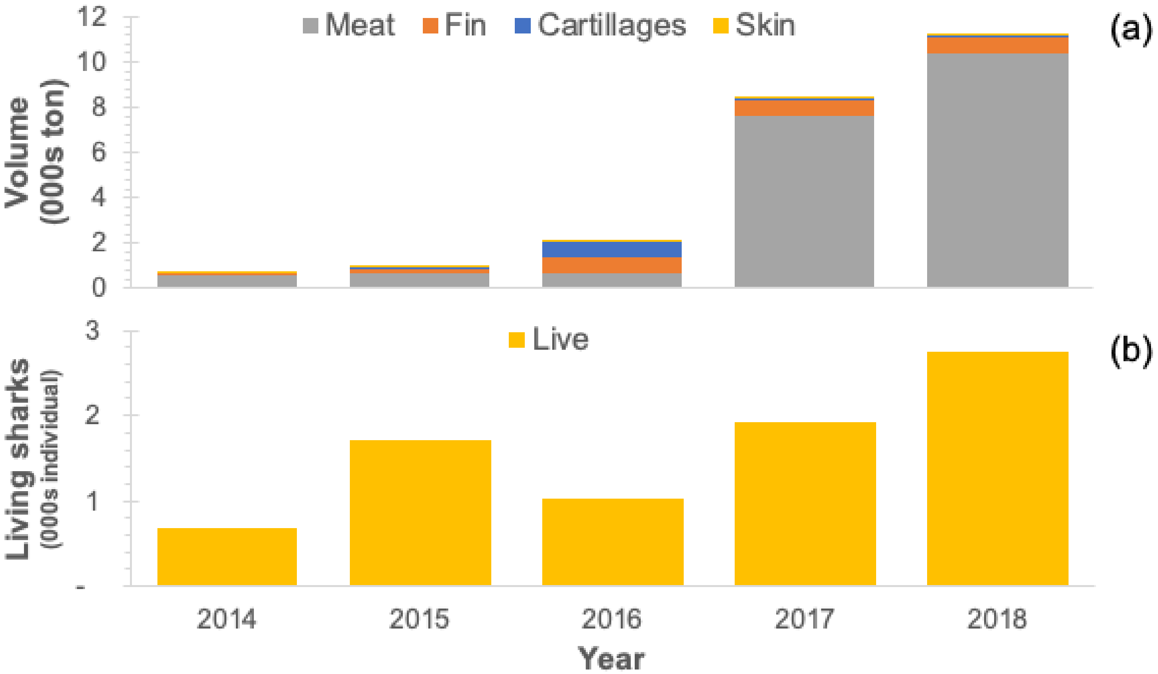

Figure 6. Export volume by products in 2014-2018 (a) and export for live sharks and rays in 2014-2018 (b). [34]

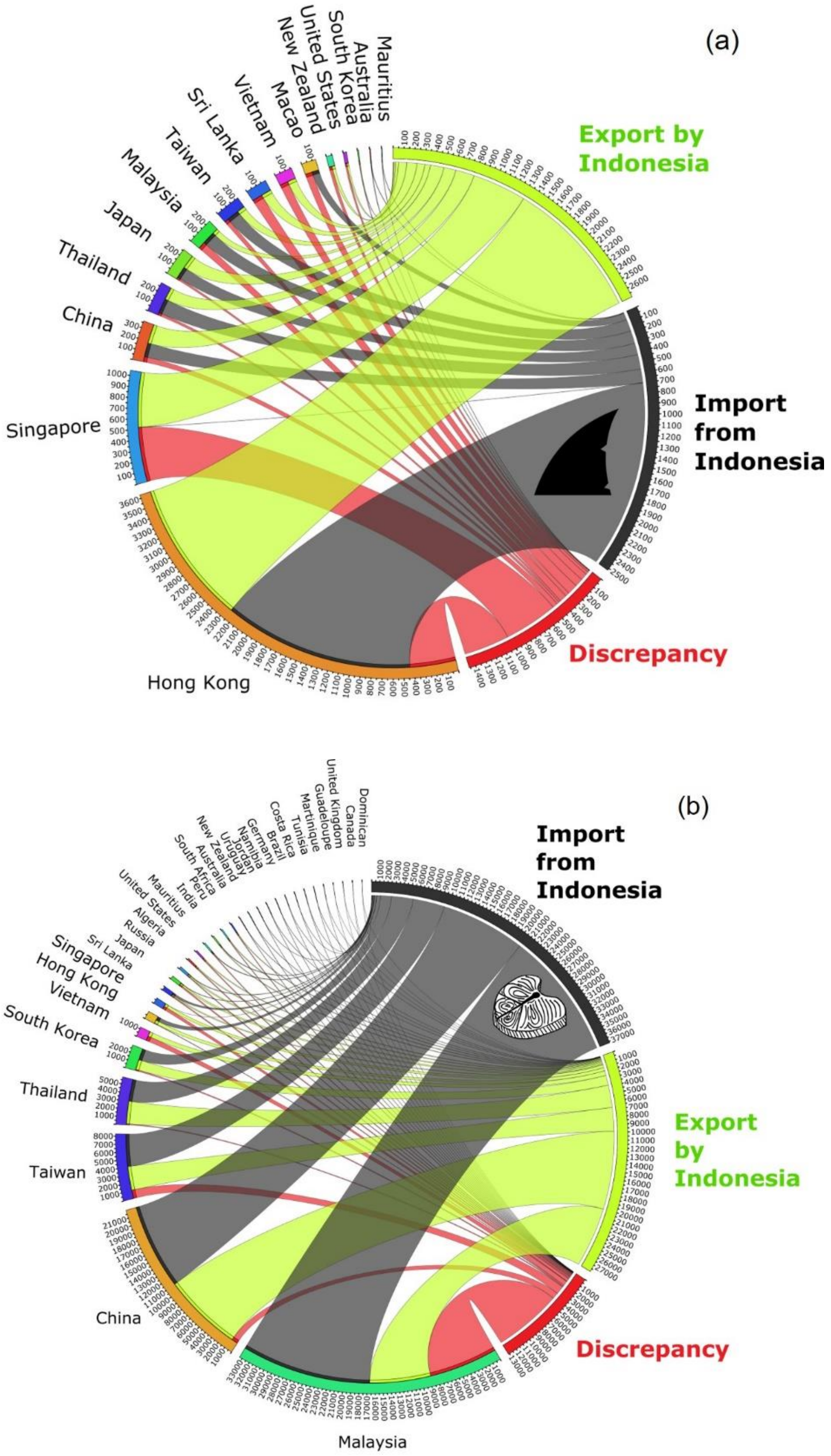

Figure 7. Trade flow and discrepancy of shark fin (a) and meat (b) products between Indonesia and its main trade partners, in tonnes, within the 2012-2018 period. Legend: Discrepancy (RED flow); the exported volume declared by Indonesia (GREEN flow), and the corresponding amount declared by each importing country (GREY flow). Source: [36]

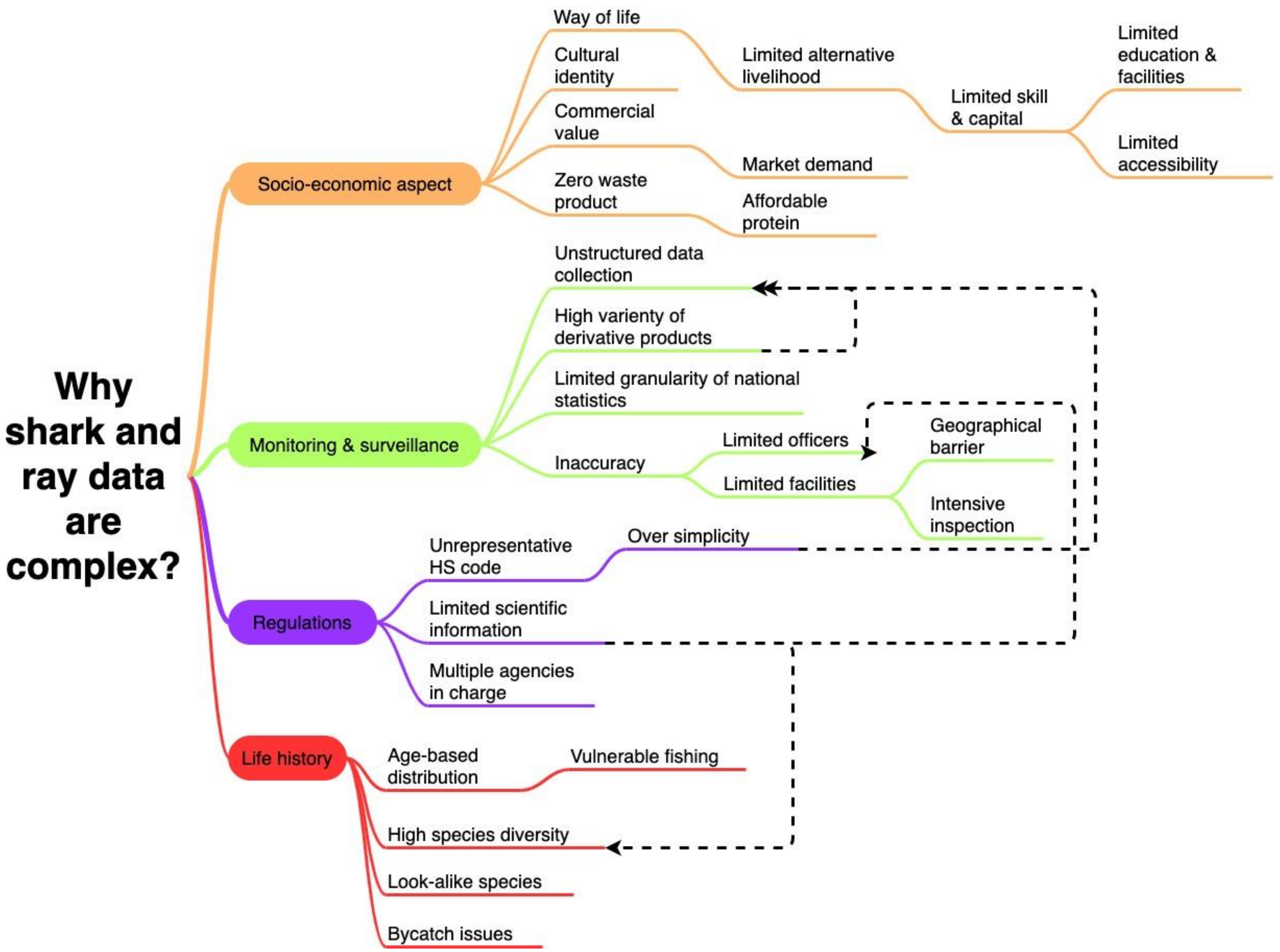

Figure 8. Causal diagram to explain the complexity of elasmobranch trade in Indonesia.