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Status of Southeast Asia's marine sharks and rays

Naomi Clark-Shen: naomi.clarkshen@my.jcu.edu.au, James Cook University Singapore, 149 Sims Drive, Singapore 387380

Andrew Chin

City Arcade, 383 Flinders Street, Townsville, QLD 4810

Sirachai Arunrugstichai

Aow Thai Marine Ecology Center, FREC Bangkok, 77 Nakhon Sawan Rd, Wat Sommanat, Pom Prap Sattru Phai, Bangkok 10100, Thailand

Jessica Labaja,

Large Marine Vertebrates Research Institute Philippines Tejero Jagna, Bohol, 6308

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Meira Mizrahi,

Wildlife Conservation Society, Myanmar Programme, No. 12(B-21,22) Narnattaw Road, Shwe Kainnayi Housing, Kamayut Township, Yangon, Myanmar

Benaya Simeon,

Fisheries Resource Centre of Indonesia, Jl. Semput No 35, Bogor

Neil Hutchinson,

James Cook University Singapore, 149 Sims Drive, Singapore 387380

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Article impact statement: Sharks and rays in Southeast Asia are understudied and overfished, and their management is socioeconomically and geopolitically challenging.

Abstract

In Southeast Asia elasmobranchs are particularly threatened. We synthesized knowledge from the peer-reviewed and gray literature on elasmobranchs in the region, including their fisheries, status, trade, biology, and management. Our assessment included x species of sharkes and y species of rays. We found that 59% of assessed species are threatened with extinction and 72.5% are in decline; rays were more threatened than sharks. Research and conservation is complicated by the socioeconomic contexts of the countries, geopolitical issues in the South China Sea, and the overcapacity and multispecies nature of fisheries that incidentally capture elasmobranchs. The general paucity of data, funds, personnel, and enforcement hinders management. Reduced capacity in the general fishery sector and marine protected areas of sufficient size (for elasmobranchs and local enforcement capabilities) are among recommendations to strengthen conservation.

Introduction

Over one-third of chondrichthyans (sharks, rays, skates and chimaeras) are threatened with extinction (Dulvy et al. 2021). Their slow life histories make them susceptible to overexploitation (Dulvy et al. 2021). Only 9% of global elasmobranch catches are biologically sustainable; 4% are managed for sustainability (Simpfendorfer & Dulvy 2017).

Although humans have long consumed sharks and rays (Kobak & Gutierrez 2004; Clarke 2014), China's economic growth in the 1980s fueled demand for shark fin soup (Fowler & Seret 2010), incentivising fishers to intensively target sharks and retain those caught incidentally (Bonfil 2002; Dent & Clarke 2015). Shark fins are a high-value product, and the value of elasmobranch meat and other parts is increasing (Clarke et al. 2006b; Dent & Clarke 2015). Elasmobranchs in the Coral Triangle, encompassing Southeast Asia, are particularly threatened (Dulvy et al. 2014), and this region plays a large role in capture and trade of elasmobranchs (Dent & Clarke 2015).

Brunei, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Timor-Leste, Thailand, and Vietnam comprise Southeast Asia. Their populations depend heavily on fishes as a main source of protein and income (Pomeroy et al. 2007, 2016). Regionally, coastal fish stocks are depleted to an estimated 5-30% of unexploited levels (Silvestre et al. 2003). There are at least 273 species of marine elasmobranch in this region (IUCN 2021). Considering their importance to ecosystems and susceptibility to threats (Fowler et al. 2005), synthesis of regionally available information for elasmobranchs will help identify data, policy, and management needs.

Methods

We used the following keywords in a literature search of Web of Science, Google Scholar, and OneSearch: *shark, stingray*, *batoid*, *elasmobranch*, *wedgefish*, *guitarfish*, *chondrichthyan*, *fish**, *Southeast Asia*, *Indonesia*, *Malaysia*, *Sabah*, *Sarawak*, *Borneo*, *Thailand*, *Vietnam*, *Timor**, *Lao**, *Myanmar*, *Burma*, *Brunei*, *Singapore*, *Philippines*, *Cambodia*. Irrelevant literature was excluded (e.g., freshwater research). A search of SEAFDEC (Southeast Asian Fisheries Development Centre), IUCN and other gray literature was also conducted. There was little relevant literature on Brunei, Timor-Leste, and Lao, so they were excluded from references to Southeast Asia unless otherwise stated. *Elasmobranch* collectively refers to sharks, rays, and chimaeras.

Results

Elasmobranch fisheries

Southeast Asia contained 3 of the top 20 elasmobranch fishing nations from 2000 to 2011 (Indonesia, Malaysia, and Thailand [Dent & Clarke 2015]) and 2 of the top 20 elasmobranch fishing nations from 2007 to 2017 (Indonesia and Malaysia) (Oakes & Sant 2019). Total landings of elasmobranchs reported to the Food and Agriculture Organisation (FAO) (Fig 1a) are likely 3-4 times lower than actual catches (Clarke et al. 2006a; Worm et al. 2013); however, reconstructed data (Sea Around Us 2021) can be used to make estimates (Fig 1b).

Indonesia, the Philippines, Vietnam, and Myanmar are the only countries with reported targeted elasmobranch fisheries (SEAFDEC 2006; DoA 2009; DoF/BOBLME/FFI 2015; Fahmi & Dharmadi 2015). Because fin value increases with size (Fields et al. 2018), shark-fin fisheries often target larger sharks; methods include longlines, hook and line, and gillnets (DoA 2009; Dharmadi et al. 2017a; DoF/BOBLME/FFI 2015). Hammerhead sharks (*Sphyrna* spp.,), wedgefishes (*Rhynchobatus* spp.), and oceanic white-tip sharks (*Carcharhinus logimanus*) are considered valuable species (DoA 2009; Dent & Clarke 2015; Jaiteh et al. 2017b; D'Alberto et al. 2019).

Indonesia and the Philippines had the largest targeted elasmobranch fisheries. Their large, archipelagic, Exclusive Economic Zones (EEZ) allow access to large, pelagic species with valuable fins (SEAFDEC 2006). They also have shark liver oil and meat fisheries (DoA 2009; Varkey et al. 2010; Jaiteh et al. 2017b). Indonesia has ray meat and skin (e.g., *Maculabatis gerrardi*) fisheries (D'Alberto et al. 2019; Clark-Shen et al. 2021). Shark fisheries developed in Vietnam in the 1980s for fins, skin, cartilage, and liver oil; catches peaked at the late1980s before declining (SEAFDEC 2006). It is unclear whether these fisheries persist. In Myanmar shark fishing was banned in 2009 yet persists (WCS Myanmar 2018), and the fisheries remain unmanaged (DoF/BOBLME/FFI 2015; MacKeracher et al. 2021). *Mobula* rays are targeted for gill rakers and meat in Myanmar (DoF/BOBLME/FFI 2015), and a thriving ray fishery (WCS Myanmar 2018) exists, largely driven by local consumption (MacKeracher et al. 2021). Fishers in Myanmar and Indonesia illegally use dynamite to kill fish and attract scavenging sharks (DoF/BOBLME/FFI 2015). These sharks are a bonus in Myanmar but compensate for decreased shark catches in Indonesia (DoF/BOBLME/FFI 2015; Jaiteh et al. 2017b). Although Thailand reports they have no shark fisheries (SEAFDEC 2006, 2017a; Krajangdara 2019), there is contradictory literature (Stevens et al. 2005; WildAid 2017), and some artisanal fishers report occasional, seasonal fishing for sharks (S.A., personal observation). Malaysia also claims to have no shark fisheries (Ahmad et al. 2018; Arai & Azri 2019); however, phrases, such as the following, occur in the literature: "sharks and rays are *mostly* caught as bycatch" (Aswani et al. 2018) and "74.3% of [fishers who catch sharks during the tuna off-season] argue that sharks are not the target species" (Ahmad et al. 2018). These inconsistencies could be due to the multispecies nature of the region's fisheries, whereby captured elasmobranchs are used, which obscures target and bycatch.

When fin values increased in the 1980s, many fishers engaged in "finning" (Jaiteh et al. 2017b): cutting off fins and discarding bodies in the sea (Bonfil 2002; Dent & Clarke 2015). In the 1990s-2000s, countries and regional fisheries management organizations (RFMOs) introduced antifinning regulations, requiring landing of whole sharks with fins attached. All Southeast Asian countries are prohibited from finning in waters under the Indian Ocean Tuna Commission (IOTC) and Western and Central Pacific Fisheries Commission (WCPFC) (Table 1). The increasing number of sharks landed whole due to antifinning regulations is believed to be partly responsible for expanding shark meat markets. From 2000 to 2011, global meat import volumes increased ~40% and value rose >60% (Dent & Clarke 2015). Preliminary information suggests that even if fin value declines, shark fishing for meat will persist (Jaiteh et al. 2017b).

Elasmobranchs in regional fisheries are largely reported as landed whole and fully used with finning described as "not rationale" by many fishers (SEAFDEC 2006; Ahmad et al. 2019). However, it still occurs. For example, in North Maluku, Indonesia, fishers fin sharks at sea because locals do not eat the meat and boats have limited storage (Ichsan et al. 2019; Jaiteh et al. 2017a).

Elasmobranch incidental catch

Most elasmobranchs captured in Southeast Asian fisheries are reportedly bycatch (SEAFDEC 2017a; Dharmadi et al. 2017), which is similar globally (Dulvy et al. 2017; Simpfendorfer & Dulvy 2017). However, many elasmobranchs are not discarded and are considered byproduct because they are landed and used, making distinctions between bycatch and targeted ambiguous (SEAFDEC 2006; Ahmad et al. 2018). Elasmobranchs are commonly caught incidentally by near-shore gillnets, trawlers, and pelagic longlines and gillnets targeting other species (Appendix S1) (DoF/BOBLME/FFI 2015; Fahmi & Dharmadi 2015; Jaiteh et al. 2017a; Ahmad et al. 2018).

Incidental capture of sharks in pelagic tuna longline fisheries is high (Blaber et al. 2009; Sulaiman et al. 2018). Reported shark catches in Indonesia tuna fisheries vary: ~11% in 2009, <7% in 2012 and 8.5% from 2013 to 2017. Stingrays (Batoidea) are also incidentally caught (Setyadji & Nugraha 2012; Sulaiman et al. 2018). In the Philippines, sharks accounted for 24% of total volume in Filipino fisheries (Guadiano 2007 in DoA 2009). Because tuna longline fisheries are often pelagic, incidental catches commonly include larger pelagic species (e.g., blue sharks [*Prionace glauca*), Mako sharks (*Isurus* spp.), and silky sharks (*Carcharhinus falciformis*) (Blaber et al. 2009; Sulaiman et al. 2018).

Nearshore fisheries - which are often multispecies and use a variety of fishing gear - catch (incidentally and targeted) mostly small-bodied elasmobranchs or immature individuals of large species (Ariadno 2011; SEAFDEC 2017a; Arunrugstichai et al. 2018; Arai & Azri 2019). This suggests nearshore fishing grounds overlap with nursery habitats of some large-bodied species (Knip et al. 2012; Arunrugstichai et al. 2018). Trawl nets accounted for 87.9% and 96.57% of incidental elasmobranch catch in Malaysia and Thailand, respectively (SEAFDEC 2006). Elasmobranchs caught in nearshore fisheries account for a relatively small proportion of total marine catch in select regional fisheries: sharks, 1.4%; rays, 0.9%; and skates, 0.1% (SEAFDEC 2017a). But ,considering the size of fishing fleets and volumes of seafood caught, this is still substantial (SEAFDEC 2017a).

Markets for elasmobranch products

Regionally, most shark parts are used and traded (Appendix S2). Stingrays are primarily used for their meat and skin (SEAFDEC 2006, 2017a).

Stingrays and small-bodied and juvenile sharks caught in nearshore fisheries are often sold fresh and whole at local markets for meat (SEAFDEC 2017a). Prices vary with species, size, processing level, season, and country (SEAFDEC 2017a). In Singapore a premium for *Maculabatis* species was attributed to the higher quality meat for barbequed stingray, and more fresh stingrays are imported for domestic meat consumption than sharks (Clark-Shen et al. 2021). In Malaysia stingray is preferentially ranked above shark for consumption (Ahmad et al. 2016). In Indonesia the bluespotted maskray (*Neotrygon* spp.) and *Telatryon* spp. are the most common rays in supermarkets and restaurants because of taste, abundance, and low price (Mardlijah & Pralampita 2004; B.S., personal observation). In the Philippines thresher shark meat is favored and has high market value (A. Ponzo, personal communication). Regional trade in fresh, whole elasmobranchs is widespread (SEAFDEC 2006, 2017a) but poorly documented, with multiple landing and aggregation sites and transport routes (Clark-Shen et al. 2021). Although fins are typically exported regionally, they are also consumed locally mainly among Chinese communities (SEAFDEC 2006; Dent & Clarke 2015).

Elasmobranch fins, meat, cartilage, and skin dominate the region's export market (Dent & Clarke 2015; SEAFDEC 2017a). Singapore, Malaysia, Indonesia, and Thailand are major global trade hubs for the import and export of elasmobranch meat and fins (Appendix S2). Large fins, of high value (Fields et al. 2018), are the primary export product, typically traded to China, Hong Kong, and Singapore (SEAFDEC 2006; Dent & Clarke 2015) (Appendix S2). *Manta* and *Mobula* gill rakers were primarily traded to China from Indonesia and Vietnam (O'Malley et al. 2016), but these species have since been listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II. Undocumented and illegal trade of CITES-listed species still occurs regionally (Friedman et al. 2018; Clark-Shen et al. 2021; Choo et al. 2021).

Trade in small, low-value fins (used for inexpensive shark-fin soup) is growing (US$1-2/processed fin) in Thailand, Malaysia, Vietnam, Hong Kong, and Japan (Dent & Clarke 2015; Fields et al. 2018; Cardenosa et al. 2020). In dried-seafood stalls in Hong Kong in 2014-2015, 48% of fins came from small-bodied sharks and chimaeras (despite large fins historically dominating the market). These are believed to have come from Southeast Asia's nearshore, multispecies fisheries (Fields et al. 2018) that catch small-bodied sharks, often incidentally (SEAFDEC 2017a). It is unclear whether the increase in traded small fins is due to large sharks declining or demand for more affordable fins.

The market for ray skins (e.g., whiprays, family *Dasyatidae*) for products, including wallets and belts, is increasing (Save Sharks Network Philippines 2017; D'Alberto et al. 2019). Thailand is a common destination for skins from Singapore and Indonesia (MMAF 2020; N.C.-S., personal observation). Stingray skins were the second most important product after wedgefish (*Rhinidae* spp.) fins in a tangle-net fishery in Indonesia (D'Alberto et al. 2019). Now that wedgefishes are listed on CITES Appendix II and should not be traded internationally by CITES signatories without a nondetriment finding (CITES 2021), stingrays may be increasingly targeted. Wedgefish snout usage in shark head soup is a delicacy in Singapore and Malaysia (Clark-Shen et al. 2021; Kyne et al. 2020).

Status of elasmobranch populations

Of 273 assessed marine elasmobranchs (117 rays, 152 sharks, 4 chimaera) in 11 countries, ~59% are considered threatened with extinction (6.6% data deficient, 19.8% least concern, 15% near threatened, 25.6% vulnerable, 22.7% endangered, and 10.3% critically endangered) (Fig 2) (IUCN 2021). Additionally, 72.5% of species have declining populations, 9.5% of species are stable, 0.7% are increasing (crocodile shark [*Pseudocarcharias kamoharai*], bluespotted lagoon ray [*Taeniura lymma*] only), and status of 17.2% are unknown. More rays are threatened with extinction (69.3%) than sharks (51.3%) (IUCN 2021). Fisheries mechanization, destructive fishing methods (e.g., trawlers), and overfishing are the main causes for regional population declines (Howard et al. 2015; Jaiteh et al. 2017a; Arunrugstichai et al. 2018).

Catch and landing trends

In Myanmar over 50% of "household heads" report declines of elasmobranch catches over the past 5 years (Howard et al. 2015). In the Philippines, fishers reported catch declines of *Mobula* ray (Acebes 2012). Indonesian fishers report declines in the number of sharks caught, primarily in the last 5-10 years (Jaiteh et al. 2017a). In Vietnam and Thailand, targeted fishing effort reportedly declined because of depleted shark numbers (SEAFDEC 2006; WildAid 2017).

These reported declines are mirrored in landings data. In the Philippines landings and catch per unit effort declined (DoA 2009). In Indonesia wedgefish landings declined ~90% from 2005 to 2008 (D'Alberto et al. 2019). From 1996 to 1997, elasmobranch catch in the Java Sea declined by 1 order of magnitude (Blaber et al. 2009). In the Philippines whale shark landings had decreased by 1997 (Alava & Dolumbalo 2002). Shifting fishing grounds suggest local depletions. In Indonesia shark fishing effort shifted from west to east (Bonfil 2002). In Thailand buyers report sharks sourced from ever-more-distant fishing grounds (Arunrugstichai et al. 2018). In the Philippines manta ray were fished farther offshore by the 1980s (Acebes 2012).

Changes in species catch composition

Fishers in eastern Indonesia report declines in large sharks caught (Jaiteh et al. 2017a), and surveys of Thailand's nearshore fisheries show declines in landings of large sphyrnid and carcharhinid species (Arunrugstichai et al. 2018). In contrast, landings surveys of nearshore, multispecies fisheries in Thailand, Malaysia, Indonesia, and the Philippines reveal bamboo sharks (*Chiloscyllium* spp.) are the most abundant species (DoA 2009; Dhamardi et al. 2015b; SEAFDEC 2017a; Arunrugstichai et al. 2018; Arai & Azri 2019). In Ranong province in Thailand, proportions of landed bamboo sharks increased from 26% in 2004 to 65% in 2016 (Krajangdara 2005; Arunrugstichai et al. 2018). This may be due to their relatively high fecundity, which makes them more able to withstand fisheries and proliferate, while larger, more vulnerable sharks become depleted, known as mesopredator release

(Sherman et al. 2020a), which may be responsible for a regional increase in the bluespotted lagoon ray as well (Sherman et al. 2020a).

Lost and rare species

Dwarf sawfish (*Pristis clavata*) have not been recorded regionally for over a century (Kyne et al. 2013); sawfishes appear to be gone from Thailand and Indonesian (IUCN Shark Specialist Group 2021); and lost shark (*Carcharhinus obsoletus*) and Java stingaree (*Urolophus javanicus*) are likely extinct (Dulvy et al. 2021; Kyne et al. 2021). However, because countries have limited monitoring and challenges identifying elasmobranchs to species level (DoA 2009; DoF/BOBLME/FFI 2015; Nijman 2015; Krajangdara 2019), undetected remnant populations may persist. For example, the clown wedgefish (*Rhynchobatus cooki*) was undocumented for over 20 years until found at a fishery port in 2019 (Clark-Shen et al. 2019a). A subsequent search of social media revealed sightings of this species in Indonesia between 2015 and 2020 (McDavitt & Kyne 2020).

Elasmobranch management in Southeast Asia

Numerous regional management initiatives explicitly relate to elasmobranchs (Table 1). Countries must adhere to RFMO regulations while fishing in the Indian Ocean and the Western Pacific Ocean, but the South China Sea is not subject to RFMOs (Zhang 2018). Therefore, SEAFDEC (2021) and the Coral Triangle (2021) Initiative play important roles in establishing management and conservation of regional resources. Elasmobranch-specific national laws focus primarily on CITES-listed species, and elasmobranch sanctuaries often occur where tourism is high (Table 2) (Topelko & Dearden 2005).

Brunei and Myanmar have banned shark fishing. We found no information on the effectiveness of Brunei's ban, prior to which 12.7% of sharks were taken as bycatch in selected fisheries (SEAFDEC 2006), and a recent study reports sharks caught as bycatch (Azri et al. 2020). Myanmar's regulations seem unenforced (Howard et al. 2015; MacKeracher et al. 2021), and there are no clear regulations on retaining or selling shark bycatch, which authorities appear to tolerate (Howard et al. 2015). Only 49% of surveyed fishers in Myanmar were aware of the shark fishing ban, citing food and income as motivations for not complying (MacKerarcher et al. 2021).

Complex regional management

Regional challenges to elasmobranch management relate to systemic issues of general fisheries (SEAFDEC 2006, 2017a; Dharmadi et al. 2017). Overcapacity is a leading cause of regional overfishing (Pomeroy et al. 2016) that arises from open access to the resource, poverty rates, subsidies, and lack of alternative livelihoods (Pomeroy 2012; SEAFDEC 2018). Other problems include absence of an RFMO to regulate activity (Zhang 2018); overefficient and destructive fishing (Ariadno 2011); and multispecies nature of many fisheries that complicates species-specific management (Salayo et al. 2008; Ariadno 2011). There are insufficient funds, capacity, technology and human resources to monitor fisheries and collect data (Pomeroy 2012; SEAFDEC 2017a); enforcement of fisheries regulations and protected areas is weak and there is corruption and illegal, unreported, and unregulated fishing (Pomeroy et al. 2015; Pomeroy et al. 2016; Kamil et al. 2017).

Presence of China

Although China is not part of Southeast Asia, it claims sovereignty over the South China Sea and fishes there (Fravel 2011). These territorial disputes cause conflict and complicate cooperative management of transboundary populations (Dharmadi et al. 2015; Zhang 2018). China is a main importer and consumer of shark fins (Dent & Clarke 2015; Oakes & Sant 2019), but their reports to the FAO do not provide true volumes or locations of catch (Dent & Clarke 2015; FishStatJ). Targeted shark fisheries in southern China collapsed between the 1970s and 1990s (Lam & de Mitcheson 2011), and reconstructed elasmobranch catches suggest a decline of 67% since the 1950s (Zeller & Pauly 2016). Reported and reconstructed unreported elasmobranch catches near disputed South China Sea islands in Southeast Asia from 1950-2016 were ~1.6 million t: 46% caught by Mainland China, 29% by Taiwan and Hong Kong, 19% by other Southeast Asian countries, and 6% by other nations (Sea Around Us 2021). Timor-Leste (outside the South China Sea) protected all sharks, discovered them onboard a Chinese vessel, and reduced protection to 12 species (Lopez-Angarita 2019).

Social and development contexts

Many fishers in Southeast Asia face poverty (Jaiteh et al. 2017a, 2017b; Save Sharks Network Philippines 2017). Therefore, even when caught in small amounts elasmobranchs provide important income (Ahmad et al. 2018; Aswani et al. 2018). Although some shark fishers may consider alternative livelihoods, they often live in areas with few options: land may be unsuitable for agriculture; regional markets distant; funds, infrastructure, and expertise to develop other income sources lacking; and tourism development difficult (Acebes et al. 2016a; Jaiteh et al. 2017b; Lestari et al. 2017; Mizrahi et al. 2019).

Some shark fishers resort to illegal livelihoods that use their skills (navigation) and resources (boats), such as human and petrol smuggling (Jaiteh et al. 2016; Jaiteh et al. 2017b). Shark fishers in Myanmar and Indonesia switched to fishing of other species; however, this was less profitable and involved learning new fishing techniques (Howard et al. 2015; Jaiteh et al. 2017b). In Indonesia a shark-fishing community successfully switched to seaweed farming until there was an oil spill and no funds to restart the project (Jaiteh et al. 2017b).

These situations demonstrate why harvesting of sharks, particularly for fins, is a viable livelihood: fins are valuable; dried fins can be stockpiled; fins are light and easily transported; and sharks can be harvested with simple gear (Jaiteh et al. 2017a). Some shark and mobula ray fishers are unwilling to adopt alternative livelihoods because of the tradition, culture, and identity associated with this work (Acebes et al. 2016b; Jaiteh et al. 2017b; Yulianto et al. 2018), and Western conservation initiatives may be rejected or incompatible with community contexts and needs (Clifton & Foale 2017).

Limited landings data

Species-specific catch and landings data are limited and mostly aggregated into sharks or rays in national statistics and FAO reports (Appendix S3) (FishStatJ, 2016). Cambodia, Myanmar, Timor-

Leste, and Vietnam do not report elasmobranch data to the FAO although it may be reported under "marine fish" (Holmes et al. 2014). Fishing gear type, fishing ground location, and size and sex of specimens are rarely reported and typically do not come from long-term monitoring programs; this limited data hinders population assessments, identifying key habitat, and creating management plans (Blaber et al. 2009; DoA 2009; SEAFDEC 2017a; Arunrugstichai et al. 2018). The Sea Around Us database provides some detail (e.g., catch volumes by gear type), but their "unreported" data are reconstructed estimates.

Reasons for a lack of data include difficulties identifying elasmobranchs to species level and limited capacity and funds for monitoring (DoA 2009; Dharmadi et al. 2015; DoF/BOBLME/FFI 2015; Krajangdara 2019). In countries with bans on shark fishing, fishers may be reluctant to share catch data out of fear (M.M., personal observation). In Thailand citizen outrage and scoldings by authorities (even when landed sharks are legal), can make sellers hide sharks (S.A., personal observaiton). Because many elasmobranchs in Southeast Asia are caught incidentally and are of low value (SEAFDEC 2017a), there may be less political will to invest in monitoring. For example, the National Stock Assessment Programme (NSAP) in Thailand only monitors landings of the 10 most commercially important species, which does not include elasmobranchs (Arunrugstichai et al. 2018). The SEAFDEC has implemented monitoring programs for elasmobranchs throughout Southeast Asia (SEAFDEC 2017b), but continuity is not yet reported.

Limited biological data and taxonomic confusion

Life-history (e.g. age, growth, breeding), behavioral, and habitat data on elasmobranchs is limited regionally (DoF/BOBLME/FFI 2015; Ahmad et al. 2018; Arai & Azri 2019), and information from one region may not be applicable to another. For example, male gray sharpnose sharks (*Rhizoprionodon oligolinx)* differ in size at maturity in India (Purushottama et al. 2017) and Indonesia (White 2007).

Taxonomic confusion can lead to unsuitable management based on the incorrect identification of species' behavior, biology, and range (Simpfendorfer et al. 2011; White & Last 2012). Genetic tools have enabled distinctions between morphologically similar species historically grouped together (White & Last 2012). For example, reevaluation of *Carcharhinus sealei-dussumieri* group resulted in resurrection of Indonesian whaler shark (*Carcharhinus tjutjot)* and redescription of the blackspot shark (*Carcharhinus sealei)* (White 2012). Both species are still recorded occasionally as *Carcharhinus dussumieri* (believed to occur only in western Indian Ocean [White 2012]) in regional landings data (Arunrugstichai et al. 2018; Krajangdara 2019). The dwarf whipray *(Brevitrygon walga)* is now considered to occur only outside Southeast Asia (Last et al. 2016), making it unclear what the species recorded as such in surveys (Appendix S1) actually is. Such ambiguities reduce confidence in landings data and species trends.

Future Management

Landings surveys should clarify whether elasmobranchs are targeted, bycatch, or byproduct to guide management (Gupta et al. 2020) and collect biological information and catch locations to determine critical habitats during different life stages and seasons (Ward-Paige et al. 2012; Heupel et al. 2018).

Analysis of DNA from tissue samples could help identify cryptic and ”lost” species (Feitosa et al. 2018; Clark-Shen et al. 2021). Because a lack of capacity and funds affects monitoring (DoA 2009; Dharmadi et al. 2015; DoF/BOBLME/FFI 2015; Krajangdara 2019), more could be done to engage fishers and traders and maximize input of local ecological knowledge, providing opportunities for collaboration, employment, research, and successful management (Acebes et al. 2016a; Ahmad et al. 2018).

Responsible elasmobranch fisheries and trade

Making elasmobranch fisheries sustainable is critical (Simpfendorfer & Dulvy 2017). Barriers include cost and complexity of certification in developing countries (Washington & Ababouch 2011). Alternatively, tailored adjustments could make fisheries more responsible.

In Indonesia, the release of all bamboo sharks above 700 mm was recommended (Fahmi et al. 2021), and in a targeted shark fishery, spatiotemporal closures, restrictions on fishing effort, and incentives to control hook numbers was suggested (Yulianto et al. 2018). Catch and trade quotas for threatened species not regulated by CITES should be considered. For example, whitespotted whipray (*Maculabatis gerrardi)* is endangered (IUCN, 2020). Their suspected decline is up to 79% (Sherman et al. 2020b), but it is traded among Singapore, Indonesia, and Malaysia in large volumes (Clark-Shen et al. 2021).

Bycatch reduction

Bycatch release programs are underway in Thailand for trawlers (Krajangdara 2019), and in Malaysia, shrimp trawlers are encouraged to release juvenile elasmobranchs, which fishers reportedly agree to because of their low value (Ahmad et al. 2018). Species' survival upon release needs consideration. Some studies indicate high levels of survival (Musyl & Gilman 2018), whereas others indicate high mortality from capture stress (Gallagher et al. 2014). Some fishers in Sabah claim that sharks caught in gillnets are already dead so discarding them would be wasteful (Ahmad et al. 2018).

Alternatively, bait restrictions, hook-type changes, and use of repellents can reduce sharks being caught, and is recommended under the Philippines' proposed shark law (Shark Conservation Act of the Philippines 2019). Electric fields, tested on gillnets in Indonesia (Aristi et al. 2018), green LED lights on gillnets (Senko et al. 2022), and magnets on fish traps (Richards et al. 2018) decrease elasmobranch bycatch. The latter deterrents are effective on stationary fishing gear but not trawls, which are considered most hazardous to elasmobranchs in certain Southeast Asian countries (SEAFDEC 2006). Turtle excluder devices (TEDs) used in multiple trawl fisheries in Malaysia (Marine Research Foundation 2019) and Indonesia (where trawls were banned but minitrawls persist [Chong et al. 1987]) may also reduce bycatch of elasmobranchs (Brewer et al. 2006; Dharmadi et al. 2015). In Australia TEDs used in prawn trawl fisheries reduce catch of larger elasmobranchs (Campbell et al. 2020)

Assessment of individual fisheries is essential (e.g., fishers in India favor release of elasmobranchs over net restrictions, fishery closures, and bycatch reduction devices because these were deemed to affect income too severely [Gupta et al. 2020]), but in general, catch-based regulations are harder to enforce than gear-based regulations (MacNeil et al. 2020).

Fisheries sector reform

Improvements to the general fishery sector is essential (Pomeroy et al. 2016) and will also ensure functioning ecosystems and prey supply. Reforms may include prohibiting subsidies that contribute to overcapacity (SEAFDEC 2018) and creating alternative livelihoods (Asiedu and Nunoo 2013). Because data are scarce in the region, the allowable biological catch (ABC) is a good tool for setting of catch species limits (Chumchuen & Chumchuen 2019; Saleh et al. 2020). Restricting fisheries in critical habitats (e.g. nursery grounds) (Birkmanis et al. 2020; Di Lorenzo et al. 2020) and reducing or eliminating destructive fishing gear, such as trawlers, would reduce bycatch and protect habitats (Ariadno 2011; Seafood Source 2016; MacNeil et al. 2020). Countries should embrace remote electronic monitoring on vessels as a cost-effective and safe way to monitor catch and ensure legality (Van Helmond et al. 2019). Southeast Asian countries and China need to cooperate on marine resources in the South China Sea (Zhang 2018; Clark-Shen et al. 2019b). The growth of cell-based and plant-based foods could help alleviate demand on ocean resources (Good Food Institute 2021).

Protected areas for elasmobranchs

Significantly higher abundances of sharks are recorded in MPAs in Raja Ampat, Indonesia, and Tubbataha Reefs Natural Park, the Philippines, than in adjacent unprotected areas (Jaiteh et al. 2016; Murray et al. 2019). Their success is attributed to their large sizes, high enforcement, and value to the local economy (Jaiteh et al. 2016; Murray et al. 2019). Southeast Asian countries committed, under the UN Convention on Biological Diversity (2020), to expand MPAs and should consider elasmobranchs in their designs. Many reefs in Southeast Asia have low elasmobranch abundance (MacNeil et al. 2020), but identification of hope spots for protection is possible and should focus on areas that would yield positive stakeholder involvement instead of displacement (Musa 2003; Kamil et al. 2017; Murray et al. 2019; Dwyer et al. 2020). Where this criteria cannot be met, fisheries management or less strict area protection (e.g., no-take zones, closed seasons) could be effective (MacNeil et al. 2020). For site-attached coral reef sharks MPAs should be >10 km^2 and for less site-attached species > 50 km^2 (Dwyer et al. 2020). Although large MPAs provide better protection for elasmobranchs, where enforcement is limited, small MPAs protecting critical habitats would enable better enforcement and overall success (MacKeracher et al. 2018). A network of MPAs for migratory elasmobranchs, similar to the Turtle Island Heritage Protected Area (which spans Malaysia and the Philippines) (ASEAN Centre for Biodiversity 2010), could be considered. Only 14% of marine parks in Southeast Asia are effectively managed (Burke et al. 2002), so assessment of the likely success of MPAs is essential. Locally managed marine areas, which give fishers and communities the power to create and manage areas (Howard 2017), could prove more successful.

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Fig 1. Elasmobranch (a) landings (FishStatJ [FAO 2016]) (excluded jurisdictions: Cambodia, Myanmar, Timor-Leste, and Vietnam, lack reporting of specific elasmobranch data to FAO; Brunei, reporting to FAO started in 2015; Singapore, volumes too low to see clearly on the graph) and (b) total reported and unreported catch from Southeast Asia from 1950 to 2016 (data from FishStatJ [FAO 2016] and Seas Around Us (SAU) (2016). Data from FishStatJ includes all reported elasmobranch landings whether caught within or outside of individual exclusive economic (EEZs). Data from SAU includes reported and reconstructed unreported elasmobranch catch within the countries' individual EEZs from their own local fleets and foreign fleets.

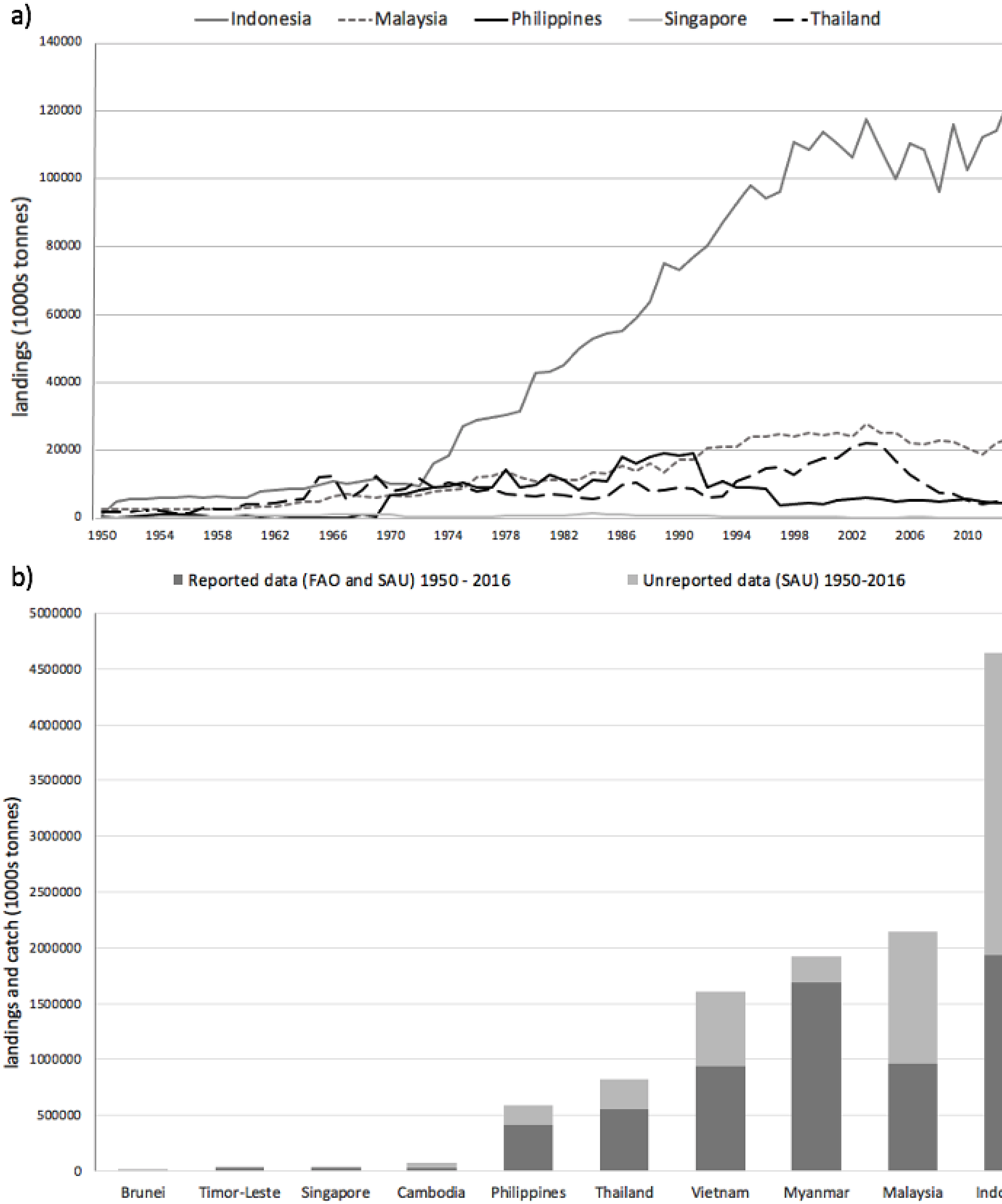
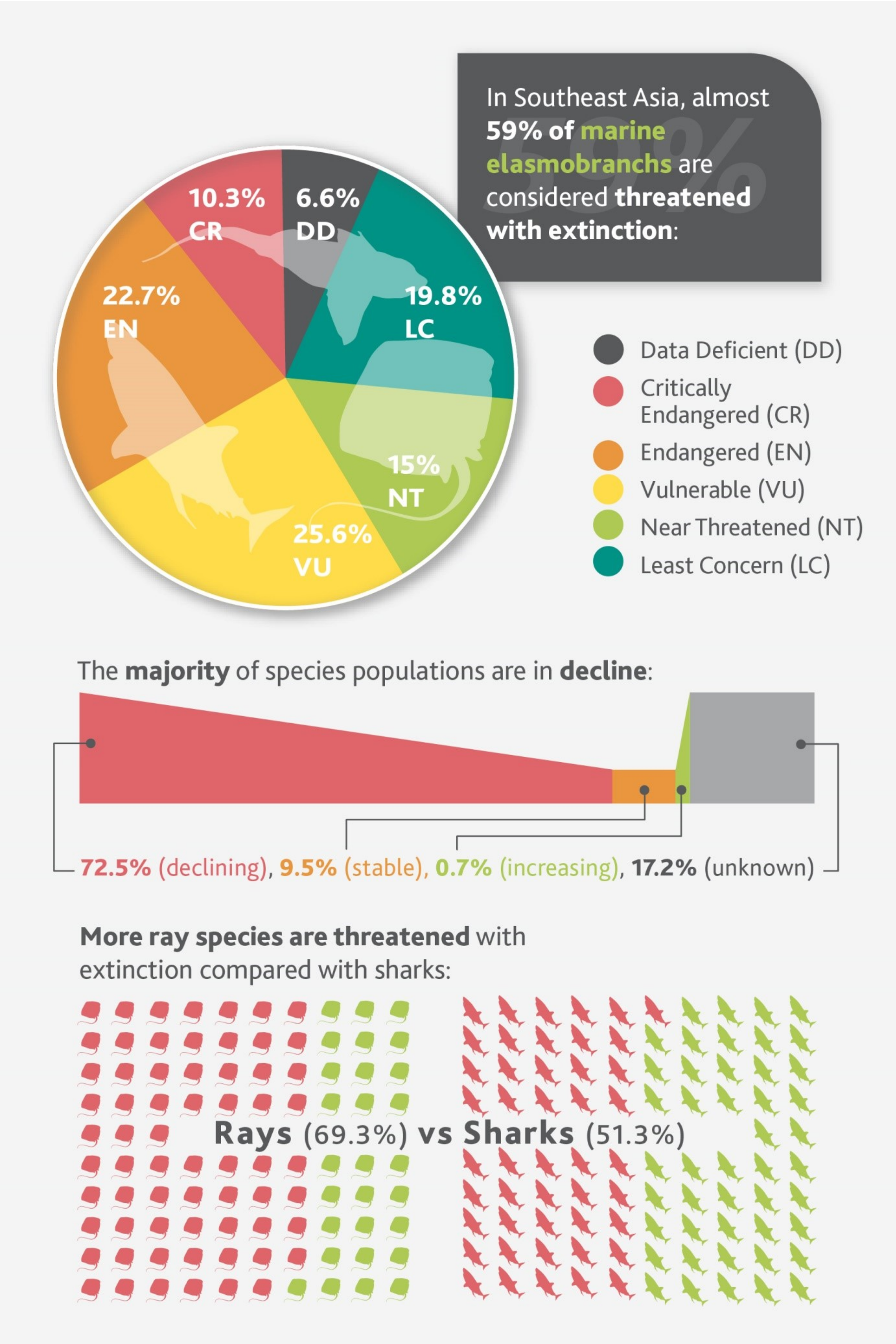

a)
Indonesia
Malaysia
Philippines
Singapore
Thailand
landings (1000s tonnes)
140000
120000
100000
80000
60000
40000
20000
0
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
2006
2010
b)
Reported data (FAO and SAU) 1950 - 2016
Unreported data (SAU) 1950-2016
landings and catch (1000s tonnes)
5000000
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
Brunei
Timor-Leste
Singapore
Cambodia
Philippines
Thailand
Vietnam
Myanmar
Malaysia

Fig 2. Status of sharks and rays in Southeast Asia. Threat categories are from International Union for the Conservation of Nature Red List (IUCN 2022)



In Southeast Asia, almost 59% of marine elasmobranchs are considered threatened with extinction:
10.3% CR
6.6% DD
19.8% LC
22.7% EN
15% NT
25.6% VU
Data Deficient (DD)
Critically Endangered (CR)
Endangered (EN)
Vulnerable (VU)
Near Threatened (NT)
Least Concern (LC)
The majority of species populations are in decline:
72.5% (declining), 9.5% (stable), 0.7% (increasing), 17.2% (unknown)
More ray species are threatened with extinction compared with sharks:
Rays (69.3%) vs Sharks (51.3%)

Table 1. Regional initiatives in Southeast Asia with relevance to elasmobranch management and conservation.

Country	CITES[a]	CMS[b]	SEAFDEC member[c]	WCPFC[d]	IOTC[e]	CTI-CFF[f]
Brunei	✓		✓			
Cambodia	✓		✓			
Indonesia	✓		✓	✓	✓	✓
Malaysia	✓		✓		✓	✓
Myanmar	✓		✓			
Philippines	✓	✓	✓	✓	✓	✓
Singapore	✓		✓			
Timor-Leste						✓
Thailand	✓		✓	✓[g]	✓	
Vietnam	✓		✓	✓[g]		

[a] Convention on the International Trade of Endangered Species, a legally binding treaty that aims to ensure that international trade does not threaten the survival of wild plants and animals.

[b] Convention on the Conservation of migratory Species of Wild Animals, uses legally binding treaties and less formal instruments to coordinate conservation measures throughout a species' migratory range. There are 40 species of elasmobranch included under CMS.

[c]Southeast Asian Development Centre, an autonomous intergovernmental body that "promote[s] and facilitate[s] concerted actions among the Member Countries to ensure the sustainability of fisheries and aquaculture in Southeast Asia," specifically countries in the Association of Southeast Asian Nations. Several initiatives relate to elasmobranchs, including the development of standard operating procedures for elasmobranch data collection and data collection at landing sites throughout Southeast Asia.

[d] Western and Central Pacific Fisheries Commission), a legally binding convention that sets provisions of fishing in the Western and Central Pacific Ocean (not including South China Sea). Several management measures relate to elasmobranchs, including live releases of whale sharks, silky sharks, and oceanic white-tips and the development of total allowable catch for targeted shark fisheries. Shark finning is prohibited.

[e]Indian Ocean Tuna Commission, associated with legally binding and nonbinding measures relating to management of tuna and tuna-like species in the Indian Ocean. Several management measures relate to elasmobranchs, including live release of thresher sharks and recording of species-specific catch data. Shark finning is prohibited.

[f] Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security, a nonlegally binding initiative with numerous goals relating to the preservation of the coral triangle marine region in the Western Pacific Ocean. Species identification training, regional assessments and national conservation plans are underway for sharks and rays.

[g]Countries cooperating nonmembers of the WCPFC.

Table 2. National laws, national plans of action (NPOA), and marine protected areas in Southeast Asian countries that were created specifically for marine elasmobranchs.

Country	National protection of elasmobranchs	Fishing gear ban	N A
Brunei	ban on the catch, landing, sale, import, and trade of all shark species since 2013 (OCEANA 2013)		
Cambodia	whale shark (*Rhincodon typus*) (FAO FIRMS 2020)		
Indonesia	whale shark (*Rhincodon typus*); giant oceanic manta ray (*Manta birostris)*; reef manta (*Mobula alfredi*); sawfish spp. (Ministerial Decree 18/2013; Ministerial Decree 14/2014) National export bans on scalloped hammerhead (*Spyrna lewini*); great hammerhead (*Sphyrna mokarran*); smooth hammerhead (*Sphyrna zygaena*); oceanic white tip shark (*Carcharhinus longimanus)* (Ministerial Decree 5/2018);	minimum mesh size for wedgefish gillnets (Ministerial Decree 18/2021)	✓

	catch quota for sharks listed on CITES (Ministerial Decree 10/2021)		
Malaysia	whale shark; sawfish spp.; great hammerhead shark; smooth hammerhead shark (*Sphyrna zygaena)*; winghead shark (*Eusphyra blochii)*; oceanic white-tip shark (*Carcharhinus longimanus)*; giant oceanic manta ray (*Manta birostris)* ; reef manta ray (*Mobula alfredi)* (Control of Endangered Species of Fish Regulation 1999 and Malaysia Fisheries Act 1998)	*pukat pari* drift nets with large mesh size to target large sharks and rays banned since 1990 (Ahmad et al. 2018)	✓
Myanmar	whale shark (*Rhincodon typus)* national ban on targeted shark fishing through a declaration made by the Department of Fisheries (Howard et al. 2015)		in

Philippines	whale shark (*Rhincodon typus)*; giant oceanic manta ray (*Manta birostris)*; reef manta ray (*Mobula alfredi)* (Friedman et al. 2018); all sawfishes *Pristidae* spp. (SEAFDEC 2020); thresher sharks protected in Batangas City (Batangas City ordinance resolution 95 s-2008); fishing and selling of sharks prohibited in Cebu (RP Provincial Board Ordinance 2015-05); Palawan protects all elasmobranchs listed in CITES Appendices or listed as critically endangered, endangered, or vulnerable by the IUCN (RP RA 7611 PCSD Resolution 19-682, PCSD Resolution 15-521); take and trade of CITES-II and III species prohibited until NDF (RP RA 8550, as amended by RA 10654)		✓
Singapore	devil rays (*Mobula* spp.) ; sawfishes (*Pristidae* spp.*)* ((Protected Wildlife Species Rules 2020)		
Timor-Leste	all sharks used to be protected but this was changed to 12 threatened species (species not listed) in or after 2018 (Lopez-Angarita et al. 2019)		
Thailand	whale shark (*Rhincodon typus)*; sawfish spp. (*A. cuspidate, P. pristis, P. zijsron*); shark ray (*Rhina ancylostoma)* ; giant oceanic manta ray (*Manta birostris)*; reef manta ray (*Mobula alfredi)*; mobula sppl (*M. mobular, M. kuhlii, M. thurstoni*) (Krajangdara 2019)		✓

Vietnam	fishing ban on CITES-listed species (Friedman et al. 2018)		