

Legal protection aspects, local community cultures, habitat, and DNA barcoding analysis of critically endangered *Sphyrna lewini* (Griffith & Smith, 1834) in Riau Archipelago, Indonesia

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Abstract. The elasmobranch species scalloped hammerhead, *Sphyrna lewini* (Griffith & Smith, 1834), commonly known as the *S. lewini*, is classified as Critically Endangered. This study aimed to analyze declining factors, such as legal protection aspects, local community culture factors, and habitat analysis of the fish in the Riau Archipelago, Indonesia. This research was carried out from March to November 2024. Primary data was collected by observing and identifying landed *S. lewini* in Tanjung Pinang City and Batam City. Interviews were conducted with fishermen, fish traders, government officials, and other community members related to the study. The *S. lewini* was identified phenotypically and then proceeded with DNA analysis. The DNA electrophoresis results referred to a single DNA marker of 500-700 bp, and phylogenetically, all samples were *S. lewini*. Some regulations regarding this species have been established in Indonesia. Unfortunately, none of them provides direct protection to *S. lewini*. At least 3 cultural things influenced the decline of this fish population: a prevalent cultural belief holds that *S. lewini* meat and fins provide health benefits to humans; consuming relatively expensive fish soup has developed into a style and prestige in society; the local community, which includes groups with traditional culinary preferences for *S. lewini*, based on dishes, also contributes to continued consumption. The study highlights the urgent need for integrated conservation policies combining legal, cultural, and ecological approaches.

Key Words: *Sphyrna lewini*, health benefit myths, consumption prestige, traditional Chinese cuisine, conservation strategies, legal protection.

Introduction. The scalloped hammerhead, *Sphyrna lewini* (Griffith & Smith, 1834), commonly referred to as the southern hammerhead or bronze hammerhead, is one of nine recognized species within the genus *Sphyrna* with a global distribution. All species are included in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), 2024, as creatures that are protected. As top predators, these animals also play a significant part in preserving the balance of the aquatic environment. Among the genus *Sphyrna*, the *S. lewini* is the most common species found in Indonesia. They are recognized by the shape of the slightly curved head tip with a curve in the middle, and the sides behind the eyes are concave. Throughout the world, this species primarily inhabits mild, temperate, and tropical coastal waters

between latitudes 46°N and 36°S, down to 500 meters (Rigby et al 2021; Amani et al 2022).

This biota is sought after because of its huge fins, which are a major component of *S. lewini* fin soup and are highly valued in Asian markets. Because of this, *S. lewini* populations are decreasing globally, and the International Union for Conservation of Nature (IUCN) has classified them as critically endangered. Over the past 50 years, *S. lewini* populations have decreased by roughly 70% worldwide, which emphasizes how vital it is to change fishing regulations and land limitations (Pacoureaux et al 2021).

Recent studies have shown that Indonesia and its trading partners' import and export data on *S. lewini* differ significantly. The domestic trade is intricate, and live *S. lewini* exports are on the rise (Dorantes-González et al 2023). The largest *S. lewini* fishing nation in the world, Indonesia, is home to one-fifth of all known species, with an average yearly landing of 110,737 metric tonnes between 2007 and 2017. Remarkably, according to the Wildlife Conservation Society, around 86% of Indonesian fisheries captured *S. lewini* as bycatch in 2018 (Ferretti et al 2020; Einhorn 2021).

Throughout their lives, the fish only reproduce in small numbers and develop and mature slowly. Instead of releasing a vast number of eggs that have a high chance of not surviving, they aim to create a limited number of highly developed chicks at birth, unlike the majority of genuine bony fish. The animals are especially vulnerable to overexploitation because of their ecological sensitivity to fishing pressures and conservative life cycles (Pincinato et al 2022; Worm et al 2024). To satisfy the rising demand for a range of consumer goods, such as fins, meat, and cartilage, have been abused and sold recently. Since 1970, the species population has decreased by 71% due to overfishing (Muttaqin et al 2019; Einhorn 2021). Because of this, several species have seen sharp drops in population, and one in four Chondrichthyan species is thought to be in danger of going extinct. *S. lewini* are therefore among the world's most threatened vertebrate species. The economic and social significance of this biota fishing in Indonesia is traded off against the objectives of *S. lewini* conservation (Mustika et al 2020; Booth et al 2021; Dulvy et al 2021).

The purpose of this research was to analyze the declining factors affecting the critically endangered *S. lewini* in the Riau Archipelago, Indonesia, with a specific focus on legal protection aspects, local community cultural factors, and habitat analysis.

Material and Method

Methods of research. This research was conducted between April and December of 2024. Samples were collected from landing ports, warehouses, and markets in Tanjung Pinang and Batam, originating from Riau Archipelago waters, Indonesia. Interviews were conducted with fishermen who usually catch *S. lewini* (30 persons), fish traders who sell the fish at the fish market (30 persons), government officials from the Riau Archipelago Province Maritime Affairs and Fisheries Department (10), *S. lewini* snack sellers (3 persons), warehouse owners (3 people) and other community members related to this research (5 persons). Respondents were randomly selected, and all interviews were conducted based on a questionnaire that had been prepared previously. The study followed the Helsinki Declaration and was ethically approved. All respondents were well informed of the goal of the study and the reasons why they were nominated as respondents. Data were analyzed descriptively to identify capture, use, and cultural trends.

Primary data was also collected by observing and identifying *S. lewini* that were caught and landed at fish landing ports, fish storage warehouses, and traditional markets where fish were sold in Tanjung Pinang City and Batam City. During the research, 30 fish were sampled. Secondary data was collected from government and private sector reports and other scientific publications related to the objectives of this research. The data obtained were then arranged according to needs and analyzed descriptively. Data were analyzed descriptively to identify capture, use, and cultural trends.

Legal protection aspects analysis. Legal protection analysis involved reviewing all national and international regulations related to *S. lewini* capture, trade, and conservation. In-depth interviews were subsequently conducted with government representatives (n = 9), fish traders (n = 5), fishermen (n = 5), and community members (n = 6). The analysis was complemented with a literature review of government reports, prior studies, and relevant publications.

Local culture aspects analysis. Data collection for the culture aspects analysis was carried out by conducting in-depth interviews with some government representatives (4 respondents), fish traders (5 respondents), fishermen (15 respondents), and other community members (16 respondents). Interview questions explored cultural beliefs, culinary practices, and community traditions related to *S. lewini* consumption. A literature review was performed to triangulate field data and strengthen interpretations.

Habitat aspect analysis. For the habitat aspect analysis of *S. lewini*, data collection focused on activities at fish landing sites, warehousing, and fish sales markets in the cities of Tanjung Pinang and Batam. Field observations were conducted at five accessible fishing sites (< 20 km from the coast) on Bintan and Batam Islands. These observations focused on habitat characteristics, fishing practices, and species distribution. In-depth interviews were conducted with 2 government representatives, 5 fish traders, 26 fishermen, and 5 community members. The interview material included respondents' knowledge of the habitat and range of the fish. This also included the types of food, fishing gear used, fishing season, and other aspects. Habitat data were supported by secondary information from previous ecological studies and government environmental reports.

Phenotypic identification. Preliminary identification was carried out by measuring and observing some physical characteristics of the *S. lewini*. Includes length, weight, body color, teeth, fins, and other physical characteristics. Identification was done by referring to some references (Clarke et al 2006b; Rigby et al 2019; CITES 2024).

Genotypic identification

Sample preparation. Randomly sampled fish were taken from newly landed fishermen's catches, from storage warehouses, and from fish being bought and sold at the fish market. Tissue samples (~5 g) were collected from freshly landed individuals and market specimens using sterile techniques. After sampling, the specimens were returned to their owners. *S. lewini* back muscle meat was cut using a sterile knife. This sample is coded and stored in an ice box containing dry ice. All samples were then sent to the laboratory for further analysis.

Extraction of DNA. At the extraction stage, mitochondrial DNA (mtDNA) tissue obtained from *S. lewini* fins was used as a sample. DNA extraction was carried out using the DNeasy kit from QIAGEN Inc., which was designed to facilitate the separation of DNA from various types of biological samples with optimal results (Mursawal et al 2023). This process ensures that the quality of the DNA is pure enough for further analysis.

Polymerase chain reaction process. PCR amplification was performed following standard protocols using FISH-F1 (5' - TCA ACCAACCACAAAGACATTGGCAC-3') and FISH-R1 (5' - TAGACTTCTGGGGTGGCCAAAGAATCA - 3') primers (Ward et al 2005), targeting mtDNA regions specific to *S. lewini*. DNA amplification was carried out using the PCR (polymerase chain reaction) technique, which involves several thermal cycles to multiply the desired DNA fragment. This stage begins with heating the PCR machine at 80°C for 10 seconds to ensure primer coverage, then continues with a pre-denaturation stage at 94°C for 3 minutes. Next, the denaturation process was carried out at 94°C for 30 seconds to separate the DNA double strands, followed by an annealing step at 50°C for 30 seconds to attach the primer to the DNA template, and extension at 72°C for 45 seconds to extend the DNA chain. This process was repeated for 40 cycles. A final

extension step at 72°C for 5 min completed the amplification (Pinhal et al 2008; Sultana et al 2018; Aguilar-Rendón et al 2020).

Electrophoresis. PCR products were visualized on 1% agarose gels stained with ethidium bromide under UV illumination.

Sequencing and data analysis. Sequence data were aligned using MEGA X (Kumar et al 2018) and compared with GenBank sequences via BLAST for species confirmation. Phylogenetic trees were constructed using the Maximum Likelihood method (HKY+G model, 1000 bootstrap replicates).

Results

Legal protection aspects analysis. This section aims to evaluate respondents' understanding of existing *S. lewini* protection regulations. The results of this research indicated that they were familiar with the *S. lewini*. Government officials acknowledged that this fish is critically endangered. They also noted the absence of specific regulations for its protection, and agreed that such rules should be issued. In contrast, fish traders, fishermen, and ordinary citizens were generally unaware of any protective regulations and disagreed with prohibitions on capturing *S. lewini* (Table 1). Overall, awareness was high among officials but low among traders and fishermen.

Table 1

Summary of respondents' responses to the Legal protection aspects analysis questionnaire

No.	Respondents	Responses of respondents (%)						
		1	2	3	4	5	6	7
1.	Government representatives (9)	100	100	100	100	100	100	56
2.	Fish traders (5)	100	20	20	20	20	20	20
3.	Fishermen (5)	100	0	0	0	0	0	0
4.	Other community members (6)	100	0	17	17	17	17	0

Note:

1. Percentage of respondents who are familiar with *S. lewini*
2. Percentage of respondents who know that *S. lewini* is a critically endangered species
3. Percentage of respondents who understand the role of *S. lewini* in the marine ecosystem
4. Percentage of respondents who are aware of regulations to protect *S. lewini*
5. Percentage of respondents who agree that *S. lewini* is protected
6. Percentage of respondents who agree that there should be regulations to protect *S. lewini*
7. Percentage of respondents who have a concept of protecting *S. Lewini*

Local culture aspects analysis. Interviews revealed that eating *S. lewini* has become part of the local culture. The fish is consumed by almost all levels of society. However, traders and fishermen were unaware of this fish's international conservation status. They tended to disagree with its inclusion on the list of nationally protected fish through Indonesian government regulations. However, consumers and government officials strongly agreed that the government regulates the conservation and protection of this fish (Table 2). These findings highlight the cultural normalization of consuming this biota.

Table 2

Summary of respondents' responses to the local culture aspects analysis questionnaire

No.	Respondents	Responses of respondents (%)						
		1	2	3	4	5	6	7
1.	Government representatives (2)	100	20	50	75	50	100	100
2.	Fish traders (5)	100	60	60	60	60	40	20
3.	Fishermen (26)	100	58	77	85	50	0	0
4.	Other community members (16)	100	75	88	100	100	88	75

Note:

1. Percentage of respondents who are familiar with *S. lewini*
2. Percentage of respondents who know that *S. lewini* is a critically endangered species
3. Percentage of respondents who understand the role of *S. lewini* in the marine ecosystem
4. Percentage of respondents who are aware of regulations to protect *S. lewini*
5. Percentage of respondents who agree that *S. lewini* is protected
6. Percentage of respondents who agree that there should be regulations to protect *S. lewini*
7. Percentage of respondents who have a concept of protecting *S. Lewini*

Habitat aspect analysis. Understanding *S. lewini* habitats enables stakeholders to identify critical areas for protection, reduce bycatch and illegal trading, and implement sustainable fishing practices. This knowledge also aids in assessing environmental impacts, preventing overfishing, and maintaining ecological balance, which ultimately supports biodiversity and the health of marine ecosystems. Knowledge of habitat analysis among government officials, fishermen, and traders is generally quite adequate. However, the understanding of the importance of conservation and protection of *S. lewini* remained low. Fishermen and ordinary consumers were not particularly concerned about habitat conservation and protection of *S. lewini*. They tended to disagree with the idea of conservation and protection of this fish being regulated by the Indonesian government regulations. Government officials showed high knowledge, while fishermen showed lower awareness.

Table 3

Summary of respondents' responses (%) to the habitat aspect analysis questionnaire

No.	Respondents	Responses of respondents (%)						
		1	2	3	4	5	6	7
1.	Government representatives (4)	100	100	100	100	100	100	100
2.	Fish traders (5)	100	80	80	80	80	20	20
3.	Fishermen (15)	100	100	100	100	100	20	20
4.	Other community members (16)	100	20	20	20	0	0	20

Note:

1. Percentage of respondents who are familiar with *S. lewini*
2. Percentage of respondents who know that *S. lewini* is a critically endangered species
3. Percentage of respondents who understand the role of *S. lewini* in the marine ecosystem
4. Percentage of respondents who are aware of regulations to protect *S. lewini*
5. Percentage of respondents who agree that *S. lewini* is protected
6. Percentage of respondents who agree that there should be regulations to protect *S. lewini*
7. Percentage of respondents who have a concept of protecting *S. Lewini*

Overall, habitat knowledge did not translate into conservation awareness. The data suggest that government officials and fishermen are generally well-informed about *S. lewini* and its habitat, which is crucial for effective management. Community members have lower awareness of specific habitat details, highlighting the need for targeted educational efforts to enhance conservation support across all stakeholder groups.

Phenotypic characters. The main phenotypic characteristics observed were: the head (1) broadened sideways, giving it a hammer-like appearance, with its width measuring less than one-third of its total length. The front edge of the head showed a slight central indentation and was notably curved (2). The first dorsal fin was tall and slightly bent, whereas the second dorsal fin was relatively short (3). The underside of the body (4) was white, and the mouth had a semi-circular shape (5). The specimens measured between 0.8 and 1.6 meters in length and weighed between 6.6 and 15.86 kg. Their teeth were small, triangular, and narrow with smooth edges, featuring more upright cusps on the lower jaw than on the upper jaw, while the front teeth had distinctly upright cusps (Figure 1). These characteristics are consistent with previous descriptions of *S. lewini*.

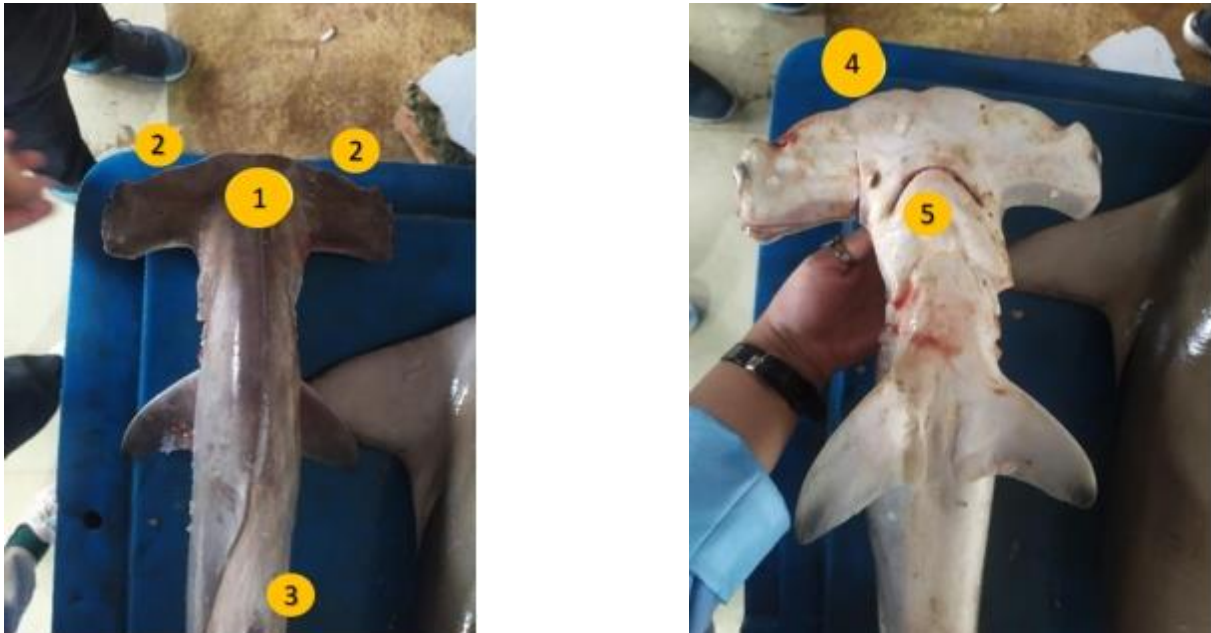


Figure 1. Electrophoresis results of *Sphyrna lewini* DNA samples.

DNA barcoding analysis. The emergence of the target band on the electropherogram confirmed successful amplification. The primer pairs utilized were unique and bonded to the anticipated location, as demonstrated by single DNA bands (Figure 2). The range matched the 500 bp primer target for COI. The DNA of the *S. lewini* was detected using a pair of primers, namely FISH-F1 (5' - TCA ACCAACCACAAAGACATTGGCAC-3') as the forward primer and FISH-R1 (5' - TAGACTTCTGGGGTGGCCAAAGAATCA - 3') as the reverse primer, which was amplified effectively. The initial circumstances, namely the primary attachment of the sample genome DNA employed, were crucial in determining the success of target amplification. All samples exhibit 100% homology levels, according to sequencing data (Figure 3). Sequencing confirmed the species identity and genetic homogeneity of all samples.

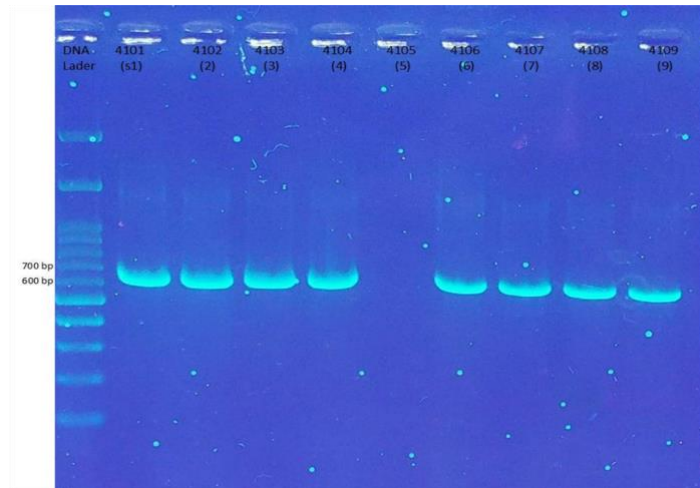


Figure 2. Electrophoresis results of *Sphyrna lewini* DNA samples (4101-4103).

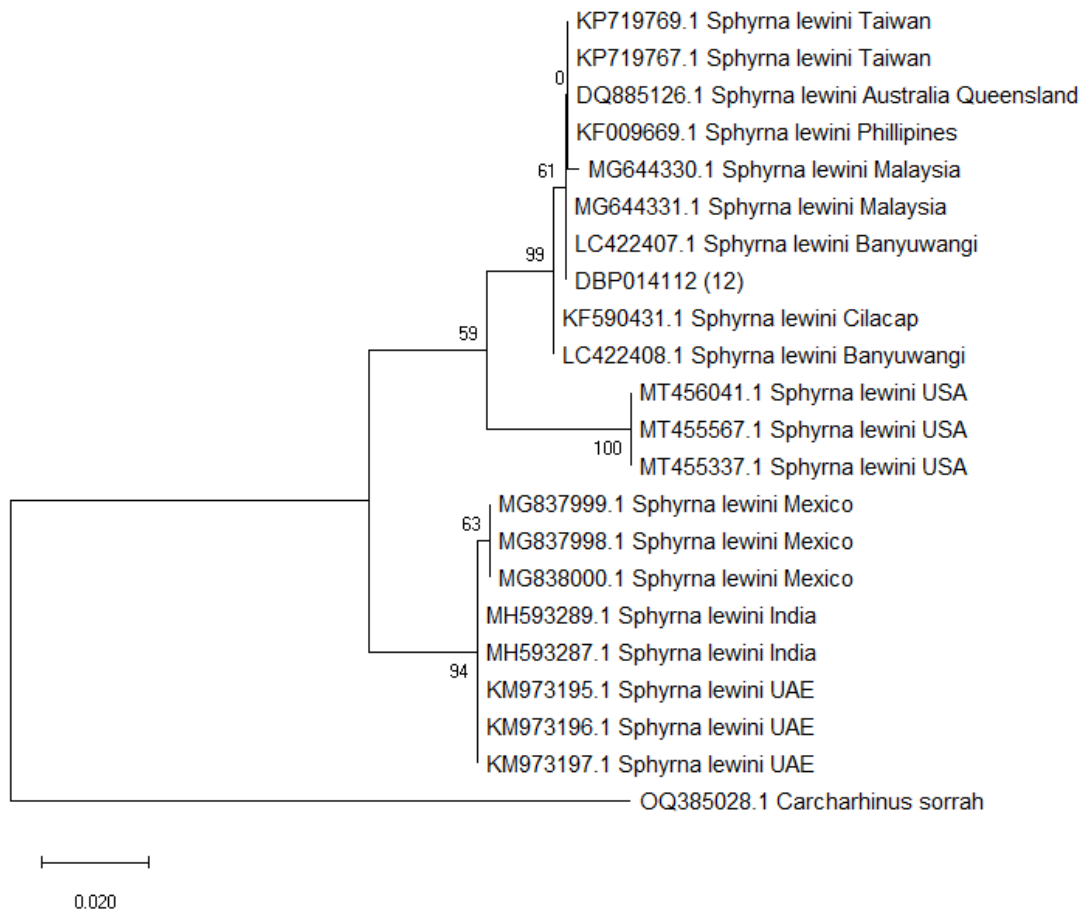


Figure 3. Phylogenetic tree with Maximum Likelihood topology generated from the mtDNA COI gene.

A phylogenetic tree was constructed to assess the relationship between the samples analyzed in this study and other sequences retrieved from GenBank. The samples collected here clustered with those from Taiwan, Australia, Malaysia, and the Philippines, as well as specific regions in Indonesia, such as Banyuwangi and Cilacap. The genetic distance within this clade ranged from 0.00 to 0.005. Additionally, the genetic distance between the samples and those from the USA was 0.033, while the distance to samples from Mexico, India, and the UAE was 0.044, 0.041, and 0.043, respectively. Overall, molecular data confirmed that all samples belonged to *S. lewini*. These findings indicate

that samples collected from Indonesian waters are closely related to populations in nearby countries, such as Taiwan, the Philippines, and Malaysia. This is a concerning observation, as overfishing or other disruptions in one region, particularly Indonesia, could significantly affect the sustainability of populations in other locations.

Discussion

Legal protection aspects analysis. These findings support the quantitative data presented earlier. Interviews with respondents revealed that biota populations in the waters of the Riau Archipelago have exhibited a consistent decline over the years. This trend is primarily attributed to the decreasing number of species resulting from intensive exploitation to meet high market demand for *S. lewini*, derived products, particularly fins. Large-bodied hammerhead sharks (*S. lewini*, *S. mokarran*, and *S. zygaena*) have become increasingly rare across most marine areas, including those surrounding the Riau Archipelago. This observation underscores the urgent need for scientifically informed conservation interventions for these species.

The IUCN has classified the *S. lewini* as Critically Endangered. Despite this designation, there remains a lack of effective management and regulatory measures for the protection of this species in international waters. The species exhibit highly migratory behavior, often moving across national boundaries, which complicates the enforcement of fisheries regulations and the prosecution of transboundary violations (Harned et al 2022).

Furthermore, their schooling behavior makes them particularly vulnerable to mass capture within a short period, thereby intensifying fishing pressure. Although a significant portion of the catch may be constituted bycatch, the morphological similarities among hammerhead species frequently lead to misidentification by fishers, posing additional challenges for species-specific monitoring and management. This highlights the urgent need for national enforcement mechanisms (Pacoureau et al 2021).

In tropical marine conservation, considerable concern has been raised regarding the long-term viability of shark populations. Globally, it is estimated that approximately one-quarter of all species are threatened with extinction, rendering them among the most imperiled vertebrate groups (Dent & Clarke 2015). The international trade in shark products, particularly meat and fins, serves as a key indicator of the scale and dynamics of exploitation within this taxonomic group.

Analyses of data from the Food and Agriculture Organization (FAO) conducted by Dent & Clarke (2015) demonstrated that the global market for *S. lewini* commodities is distinctly segmented between its meat and fins. The consumption of the species' fins is concentrated primarily in East and Southeast Asian nations, notably China, Hong Kong, Taiwan, Singapore, Malaysia, and Vietnam. Between 2000 and 2011, China and Hong Kong functioned as the principal centers of the international *S. lewini* fin trade, while Thailand emerged as a major global processing and distribution hub between 2007 and 2011 (Dent & Clarke 2015; Dharmadi & Satria 2015; FAO 2015).

According to the Ministry of Marine Affairs and Fisheries of Indonesia, marine biologists have urged the government to strengthen legal frameworks aimed at conserving *S. lewini* populations, which have shown a significant decline in recent decades. To ensure the sustainability of this biota fisheries, several management measures have been recommended, including the prohibition of *S. lewini* fin trade, the regulation and restriction of fishing gear dimensions, the establishment of catch quotas, and the legal protection of endangered *S. lewini* species. The selection of fishing equipment must be carefully controlled, with the use of large-scale nets and non-selective gear minimized to reduce bycatch.

Pregnant females are frequently captured, exacerbating the decline in *S. lewini* populations. Data from the IUCN indicate that animals are currently facing a high risk of extinction, with only an estimated 31% of their historical populations remaining. Indonesia is recognized as one of the world's biodiversity hotspots, hosting approximately 225 of the 1,250 known species of cartilaginous fishes. Commercial *S. lewini* fishing in Indonesia began in the 1980s and has since expanded in response to increasing global market demand for its products (White et al 2006; Fahmi & Dharmadi 2015).

In Indonesia, *S. lewini* products are commonly marketed in partially processed forms, typically dissected, dried, or frozen, and often display a high degree of morphological similarity among species. The domestic market's limited demand for species-specific products, coupled with low consumer awareness regarding sustainable and traceable sourcing, constrains the development of responsible trade practices. This condition facilitates various forms of fraud, including intentional species substitution and mislabeling, as it becomes increasingly challenging for traders, consumers, and regulatory authorities to verify the species identity and the ethical or sustainable origin of *S. lewini* derived products. Such practices not only undermine consumer health and food safety but also pose serious threats to the conservation of endangered and protected species, the integrity of sustainable fisheries management, and efforts to combat illegal, unreported, and unregulated (IUU) fishing. Mislabeling and species substitution thus represent critical obstacles to effective conservation and governance in Indonesia (Hebert et al 2003; White et al 2006; Muttaqin et al 2019).

S. lewini conservation and management in Indonesia are governed under several national legal instruments as follows:

- Law No. 7 of 1999 of the Republic of Indonesia (Government of the Republic of Indonesia 1999) provides full legal protection for the sawfish (*Pristis microdon*), prohibiting its utilization for both personal and commercial purposes.
- The Decree of the Minister of Marine Affairs and Fisheries No. 18/KEPMEN-KP/2013 (DMMAF, 2013) confers full protection status on the whale shark (*Rhincodon typus*),
- Decree No. 30/KEPMEN-KP/2023 (DMMAF 2023) extends protection to the walking shark (*Hemiscyllium* spp.).
- Regulation of the Minister of Marine Affairs and Fisheries No. 59/PERMEN-KP/2014 (MMAF 2014) prohibits the export of oceanic whitetip sharks (*Carcharhinus longimanus*) and hammerhead sharks (*Sphyrna* spp.), recognizing their ecological vulnerability and international conservation concern.
- Law No. 45 of 2009 on Fisheries Resource Protection (Government of the Republic of Indonesia 2009) and Law No. 5 of 1990 on the conservation of living natural resources and their ecosystems (Government of the Republic of Indonesia 1990), both of which form the broader legal basis for marine biodiversity conservation in Indonesia.

However, despite these regulatory measures, no specific or effective legal instrument currently provides direct protection for the *S. lewini*, leaving the species vulnerable to continued exploitation. In other words, although several laws exist, none provides species-specific protection for *S. lewini*.

Local culture aspects analysis. Cultural and social behaviors also contribute to species decline. Three key cultural beliefs contribute to the exploitation of the *S. lewini*. A long-standing cultural belief that its meat and fins possess health-enhancing properties, such as improving stamina, endurance, and male vitality, has perpetuated their consumption in Indonesia, where the fin soup is regarded as a prestigious delicacy, and in regions like the Riau Islands, with a significant ethnic Chinese population. The consumption of *S. lewini* meat has become ingrained in local Malay culinary traditions through products such as *S. lewini* meatballs, nuggets, and fried *S. lewini* flour, which are widely available in public markets (Barbosa-Filho et al 2019; Amani et al 2022). This species is highly prized for its fins and skin, although its meat is also marketed. Up to 5% of the Chinese fin market has been made up of *S. lewini* fins (Clarke et al 2006a). Up to 2.7 million *S. zygaena* or *S. lewini* make up this 5% (Clarke et al 2006b).

Economic pressures and household livelihood needs have driven many fishing communities to prioritize short-term income over the long-term sustainability of marine resources. In the Riau Islands, traditional fishing practices remain a deeply rooted cultural activity; however, population growth and rising food demand have intensified fishing efforts and expanded the use of fishing gear. If these trends persist, they may surpass the ecological carrying capacity of local waters, leading to further depletion of fish populations. Consequently, the economic imperatives of fishing households often overshadow awareness and practices of resource conservation (Amani et al 2022; Effendi

et al 2024). These findings underline how cultural norms and economic necessity intertwine to perpetuate *S. lewini* exploitation.

Habitat aspect analysis. Habitat accessibility further exacerbates population decline. The habitat areas are relatively easy to access by fishermen and urban communities, for example, by residents whose hobby is fishing. Fishing in the sea, including *S. lewini* fishing, is a cultural pleasure for a group of people. So, apart from being a consumption fish, the animals are also game fish that are much sought after by anglers for leisure and sporting needs (Guay et al 2021; Martinazzo et al 2022). This also makes the situation worse and accelerates the rate of population decline in certain areas (Maguire et al 2006).

The decline of the *S. lewini*, classified by the IUCN as an endangered species, is closely linked to its habitat, which overlaps extensively with human activity. This species inhabits coastal and pelagic zones, ranging from shallow nearshore waters to depths of around 275 meters, and is often found around islands, continental shelves, estuaries, and deeper offshore areas (Compagno 2005). Juveniles typically migrate along shallow coastlines, making them particularly vulnerable to fishing pressure, while adults spend most of their time offshore, forming sex-segregated groups and hunting near the surface at night. In the Riau Archipelago, fishermen operating in both coastal and offshore waters frequently capture the species as bycatch, especially in artisanal and tuna fisheries (Drew et al 2015; Fahmi & Dharmadi 2015).

The findings of this research substantiated that *S. lewini* predominantly consume teleost fish along with a diverse array of invertebrates, in addition to other species and rays. Their hunting and dietary preferences align with those of the same species or habitats as those exploited by commercial fishermen. Consequently, this behavior renders them susceptible to the fishing apparatus utilized by these fishermen. The typical prey for this species comprises small schooling fish, including sardines, conger eels, various reef fish taxa, squid, octopus, crustaceans, and smaller elasmobranchs such as blacktip reef sharks, angel sharks, and stingrays. Frequently, upwards of 50 stingray spines are discovered within the oral and digestive cavities of *S. lewini*. The biotas are categorized as formidable predators with a diet that encompasses fish, squid, and shrimp. These species inhabit temperate waters adjacent to coastlines and continental shelves (Torres-Rojas et al 2010; Rojas et al 2012; Estupiñán-Montaña et al 2021).

As opportunistic and generalist predators, *S. lewini* consume anything that is plentiful and accessible in their environment. Males and females consume the same food; however, larger animals are reported to consume larger prey than smaller, younger *S. lewini*. Adult fish consume both fish and huge creatures that inhabit deeper waters, whereas juvenile fish mostly consume fish in coastal regions. (Torres-Rojas et al 2006; White et al 2006). Habitat overlap with human activities amplifies fishing pressure and vulnerability.

Phenotypic characters. The *S. lewini* can be distinguished from other hammerhead sharks by the shape of its head. The front edge of the cephalofoil has a deep central notch with smaller curved notches on each side, giving it a characteristic "scalloped" appearance. The head is broadly arched, and the mouth is wide and slightly curved. The body is streamlined and moderately slender, with a large first dorsal fin located above or just behind the pectoral fins, and a smaller second dorsal fin positioned in front of the upper caudal fin. The pelvic fins have straight rear edges, while the anal fin has a distinct notch (Compagno 2005).

In terms of color, *S. lewini* typically has a grey, bronze, or olive upper body and a white underside, which helps with camouflage. Males are generally smaller, reaching lengths of about 1.5-1.8 m and weighing around 29 kg, whereas females grow larger, reaching up to 2.5 m and about 36 kg at maturity (Miller et al 2013). These features are consistent with previous morphological descriptions in Indo-Pacific populations.

Warm tropical and subtropical waters are home to this species. The most prevalent species in the tropics, it can be found from the surface layer down to 275 meters on continental shelves and archipelagic waters. The Sphyrnidae family of sharks

includes the *S. lewini*, which is frequently captured in Indonesian seas (White et al 2008), particularly in the southern Indian Ocean of Java and Nusa Tenggara (Chodrijah & Setyadji 2015; Fahmi & Dharmadi 2015). This is consistent with the state of the waters surrounding the Riau Archipelago, which has a tropical climate with coral reefs growing over shallow, transparent waters. It was not surprising that this species is present in the study region.

DNA barcoding analysis. Molecular evidence complements the morphological identification. Similar results have been reported by some researchers, where the molecular weight of scalloped hammer shark DNA is below 500 bp. (Pinhal et al 2008; Aguilar-Rendón et al 2020; Cardeñosa et al 2020). Misidentified species impacted by fisheries in numerous nations have already been classified using molecular identification. The majority of studies identify species using a single molecular marker in addition to the conventional morphological identification method (Abercrombie et al 2005). We looked into the species that were predicted to be landed and traded in a few fish harbors in Tanjung Pinang and Batam, Riau Archipelago, using DNA-based species identification. Molecular identification of processed flesh or specimens lacking distinctive body components is a highly effective technique for species identification and law enforcement, as the illegal trafficking of threatened *S. lewini* species is a global conservation issue (Feitosa et al 2018). Barbuto et al (2010) and Armani et al (2015) stated that DNA sequences with at least 98% similarity are considered the same species. Bhattacharjee et al (2012) explained that similarity values of 97-100% are strong matches, 92-96% are acceptable, and values below 91% indicate no species match in the GenBank database. Overall, molecular data confirmed that all samples belonged to *S. lewini*. Genetic proximity across regions emphasizes the need for regional conservation coordination.

Conclusions. This study provides an integrative overview of biological, legal, and cultural aspects influencing *S. lewini* conservation. Indonesia has several *S. lewini* protection laws, but none directly protect this fish. Three main cultural drivers myth of health benefits, the prestige of its fin consumption, and ethnic culinary traditions, contribute to population decline. These sociocultural drivers interact with ecological factors such as habitat overlap with human fishing grounds. Both morphological and molecular analyses confirmed all specimens as *S. lewini* with 100% homology. The results highlight the urgent need for an integrated conservation policy combining legal reform, education, and habitat protection.

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