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The Importance of Understanding the Current Status of Critically Endangered Species in Shark Fisheries in Muncar, Indonesia

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Abstract. One-third of all elasmobranch species are classified as globally threatened (i.e., vulnerable, endangered, or critically endangered) according to the IUCN Red List of Threatened Species, The Sphyrnidae family, once among the most abundant shark species complexes, now faces one of highest extinction risks by the IUCN in 2019. This study aimed to analyse the total catch of Sphyrnidae in Muncar, East Java, Indonesia, from 2020 to 2023, and to evaluate the proportion of Sphyrnidae catches relative to other shark during this period. The research utilized both primary and secondary data sources, with daily enumeration conducted, using guidebooks, rulers, hand scales, cameras, code tags, plastic mats, and identification books. The results revealed that most Sphyrnidae catches over the past four years were *Sphyrna lewini,* with 653 females and 433 males recorded. In contrast, *Sphyrna mokarran* and *Sphyrna zygaena* were only landed in minimal numbers over the entire period. Furthermore, *S. lewini* accounted for less than 15% of the total shark catch, with an average of 58 shark species caught annually. The use of fishing gear by fishers operating vessels under 5 Gross Tonnage (GT) with gillnets in the 10-28 GT range with longlines was identified as significant factor influencing catch composition."

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1 Introduction

Sharks play a crucial role in maintaining the health and balance of marine ecosystems [1], [2], [3], yet their populations are facing unprecedented declines due to overfishing, habitat destruction [4], [5], and the demand for shark fins [6]. Among the most threatened groups are species within the family Sphyrnidae, commonly known as hammerhead sharks, which have experienced significant population declines in recent decades. The International Union for Conservation of Nature (IUCN) classified several species within this family as critically endangered, with particular emphasis on species like *Sphyrna lewini* (scalloped hammerhead), but *Sphyrna mokarran* (great hammerhead), *Sphyrna zygaena* (smooth hammerhead shark) which are highly vulnerable to overfishing due to their slow reproductive rates and late maturity [7], Sharks within the Sphyrnidae family are characterized by life history traits that make them particularly vulnerable to overfishing. These species tend to have slow reproductive rates, producing relatively few offspring over long intervals. Additionally, they reach sexual maturity later in life, which further limits their ability to replenish their populations when faced with high fishing pressure quickly [8,9].

Indonesia is recognized as one of the top shark-fishing nations globally, and it plays a pivotal role in shaping the future of shark populations [10,11]. The country's vast marine resources and extensive fishing activities have led to significant exploitation of shark species, making Indonesia a critical player in the global shark trade [12,13]. At the same time, Indonesia holds the potential to lead conservation initiatives that could safeguard these vulnerable species [14,15]. East Java is the province that has a significant shark landing in Indonesia. Surabaya is the main hub for exporting fish products, including shark fin. Muncar fishing port in East Java, a major hub for shark landings, stands out as one of the largest shark landing sites in the region [14]. Its substantial contribution to regional shark catches underscores the importance of understanding the dynamics of shark exploitation in this area [16]. Despite its prominence, there is a concerning lack of detailed data on the composition and proportions of different shark species caught at Muncar, particularly the endangered Sphyrnidae family. This information gap poses a significant challenge to the development of targeted and effective management and conservation strategies for these critically endangered species [2,17].

This study addresses the gap by assessing the catch composition and proportion of Sphyrnidae sharks in Muncar, East Java, over four years (2020–2023). By understanding the dynamics of Sphyrnidae catches and their contribution to the overall shark catch in the region, this research aims to inform conservation strategies for these critically endangered species and highlight the need for sustainable fisheries management. Therefore, the specific objectives of this research are: (1) to assess the catch composition of Sphyrnidae sharks in Muncar; (2) to assess the proportion of Sphyrnidae sharks within the total shark catch in Muncar; and (3) to inform conservation strategies for sustainable shark fisheries management in Muncar.

2 Methodology

2.1 Study Site

This study was conducted at the Brak Fish Market (TPI Brak), Muncar, and the Muncar Fishing Port. Muncar has become a major hub for fisheries activity in East Java, hosting a combination of traditional and industrial fishing operations. The presence of a canning fish industry further strengthens its role as a key centre for fisheries in the region. Muncar also become one of the largest shark landing sites. Shark fishing has been carried out by fishers in Muncar for several decades. Shark data collection has been conducted by Mobula Project Indonesia since 2019.

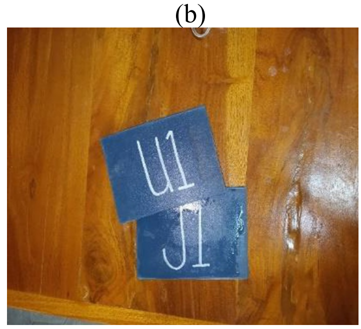
2.2 Sampling method

The shark landing data collected consists of biological data, including morphometric, meristic, sexual, claspers maturity, and catch data. The data is collected by enumerators using equipment such as scales, measuring tools, plastic mats, tag codes, and logbooks. Each day, the data is entered into the provided logbook. The equipment can be seen in the figure below.

(a)

(b)

(c)

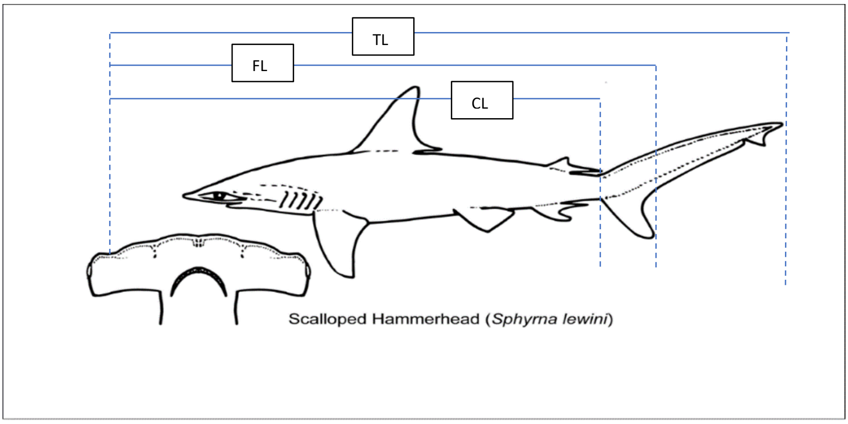


(d)

Fig. 1. (a) rulers, (b) hand scales (c) plastic mats (d) code tags

2.3 Measurement

Biological data is collected from each landing, with a minimum sample size representing 30% of the total individuals. This data is gathered daily, ensuring that at least 30% of the individuals from each species are sampled (Singarimbun et al. 1995 in [18]. While the aim is to sample 30% for daily enumeration, the enumerators strive to measure all shark species landed, depending on the number of shark landings. Measurements taken include Total Length (TL), Fork Length (FL), and Caudal Length (CL), as illustrated in the accompanying image. Sex determination is conducted by examining the presence of claspers, which are the sexual organs of male fish. This method ensures accurate data collection on size and sex composition for further analysis.



(Source: Modified from Gallagher and Klimley, 2018) [18]
Fig. 2. Scalloped Hammerhead (*S. lewini*)

(i) (ii)
Fig. 3. (i) *Cloaca* (Female Reproduction) and (ii) *Clasper* (Male Reproduction)

2.4 Data analysis

The data obtained, such as the number and types of sharks, were analysed using visual charts. The proportion of the catch composition by species was calculated using the following equation.

$$P = \frac{ni}{N} X\ 100\% \qquad (1)$$

Description:
P = Proportion of fish species caught (%)
ni = catch of shark (per individual)
N = total catch of all sharks (Individual)

A descriptive quantitative analysis using numbers and percentages, presented through charts, was also employed to explain the types of landed sharks, the composition of *Sphyrna lewini*, and its proportion in the total shark catch. The data was analysed using a combination of tools, including MS Excel, RStudio, and RawGraph.

3 Results and Discussion

3.1 Results

Muncar is famous for fishing sharks which have long been glancing for many years. Typically, fishermen have GT fishing licenses and run vessels of 24 GT up to 30 GT Sharks are caught with the help of longlines around 5000m long; the hooks are set at intervals of 25 to 30 meters. The main fishing grounds are in the Bali Strait, Bali Island offshore waters trout located in the vast area of the north, a critical regional marine ecosystem. Figure 4 illustrates the shark species caught by fishers in Muncar, Indonesia, categorized by their respective families. The shark landing data from Muncar reveal a diverse composition of species across multiple shark families. The most abundant families represented in the catches are Carcharhinidae, Sphyrnidae, Alopiidae, and Galeocerdoidae. These families consist of several species that vary significantly in life history traits and conservation status.

3.1.1 Family Composition

a) Carcharhinidae

Dominating the landings, species such as *Carcharhinus falciformis* (Silky shark), *Carcharhinus brevipinna* (Spinner shark), and *Carcharhinus melanopterus* (Blacktip reef shark) form a significant portion of the catch. Based on the result of Ichsan's research [19] in South West Aceh showed that Most catches are also sharks (Family: Carcharhinidae) such as silky shark (*Carcharhinus falciformis*) and spot-tail shark (*Carch arhinus sorrah*). The prominence of *Carcharhinus falciformis* indicates high exploitation of pelagic shark species, which could have substantial ecological consequences considering the role these sharks play as apex predators in marine ecosystems.

b) Sphyrnidae

Sphyrna lewini (Scalloped hammerhead) is notable in the catch, reflecting the vulnerability of this critically endangered species to overfishing. The presence of hammerheads in the landing data calls for urgent management measures, as these species are known for slow reproductive rates, making them highly susceptible to population declines [9]. Moreover, research carried out by Muslih [19] reveals that the highest number of male and female *Sphyrna lewini* catches occurred in August in the waters of the Java Sea and Kalimantan.

c) Alopiidae

Alopias pelagicus (Pelagic thresher) is a key species in this family, also considered vulnerable due to its slow growth and low reproductive rates. The consistent landings of thresher sharks suggest they are regularly targeted or bycatch in local fisheries. Meanwhile, research conducted by Pritiningsih [20] showed that the composition of shark species in the waters of the Southern Indian Ocean off Java, landed at the Cilacap Fishing Port (PPS Cilacap), consists of 16 species, dominated by the pelagic thresher (*A. pelagicus*), with the main fishing gear used being shark longlines.

d) Galeocerdoidae

Galeocerdo cuvier (Tiger shark) represents another high-profile species that, while more resilient than others, is also vulnerable to overfishing due to its late maturity and low reproductive rate. The dominance of apex predators like Carcharhinus, Sphyrna, and Alopias species highlights the potential overexploitation of large shark species in the Muncar region. Given the life history traits of these species—long gestation periods, late maturity, and low fecundity, their populations are likely to be severely impacted by continued unregulated fishing activities [21]. The large proportion of vulnerable or endangered species in the catch, especially from the Sphyrnidae underscores the urgent need for species-specific conservation strategies.

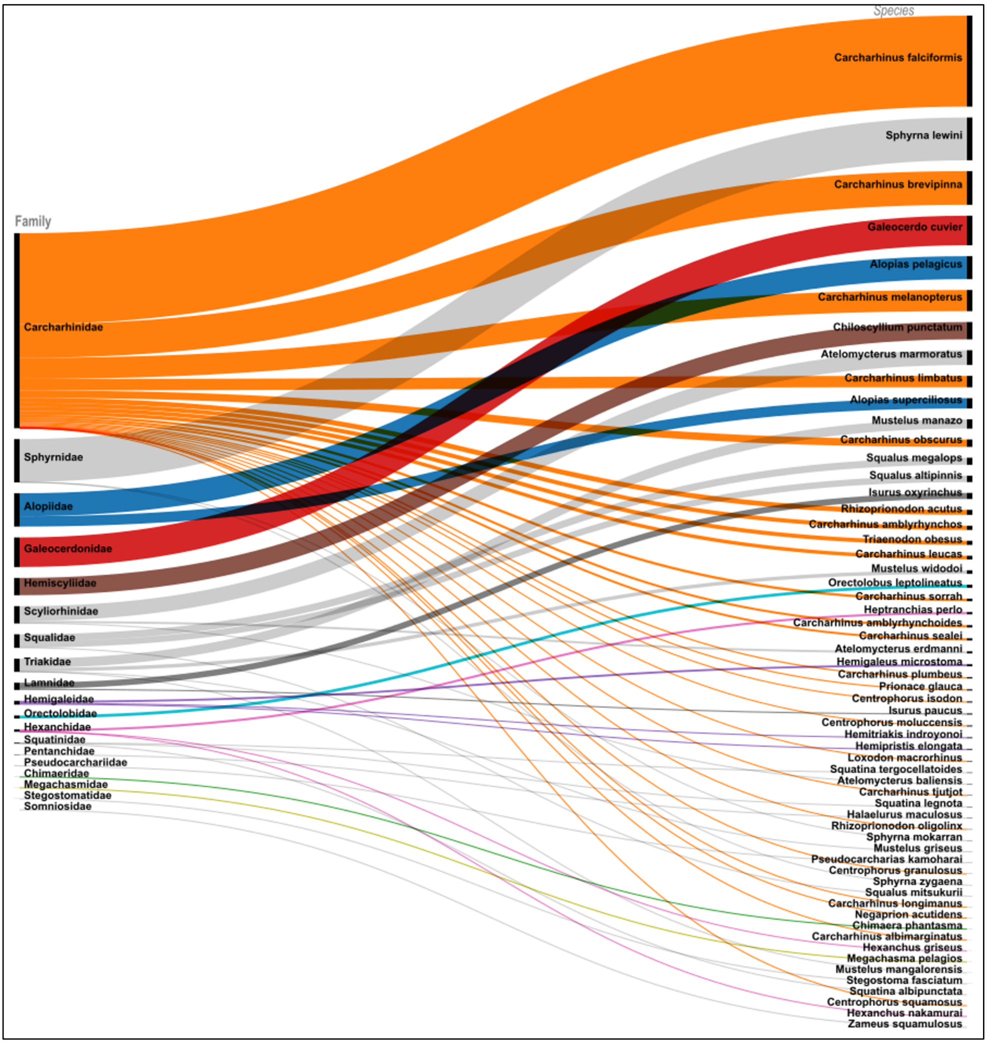


Fig. 4. Sharks species landing in Muncar (2020-2023)

The majority of Sphyrnidae catches were *Sphyrna lewini* (Figure 5), with 653 females and 433 males recorded from 2020 to 2023 (Figure 6). In contrast, neither *Sphyrna mokarran* nor *Sphyrna zygaena* was captured and landed in Muncar.

Fig. 5. *Sphyrna lewini*

The scalloped hammerhead (*Sphyrna lewini*), a critically endangered species, exhibits significant annual fluctuations in catch composition in Muncar, East Java, from 2020 to 2023 (Figure 6). The annual catch shows variations, with the highest recorded in 2021: 221 females (52%) and 201 males (48%). In contrast, the lowest catch occurred in 2020, with 114 females (62%) and 69 males (38%). These fluctuations, along with a consistent trend of females outnumbering males, suggest sex-specific vulnerability or different spatial patterns in fishing activities within this area. Furthermore, the data highlights the potential impact of fishing pressure on the reproductive segment of the population, as the higher catch rate of females could disproportionately affect the species' reproductive capacity.

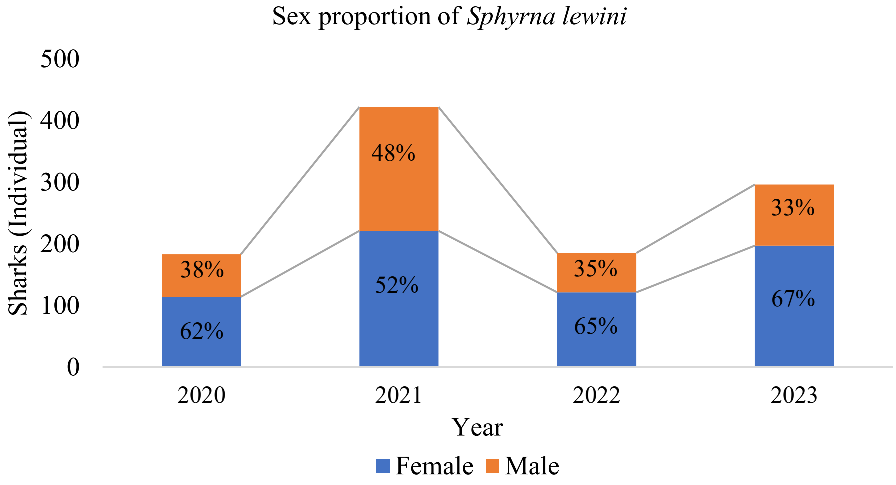


Fig. 6. Total catch of Spyrna lewini (2020-2023)

The Data on catches of *Sphyrna lewini* (scalloped hammerhead shark) exhibited clear seasonality, with significant peaks occurring at the end of August and December in every year from 2020 to 2023, indicating that these two months are essential seasons to catch this species due potentially to their migratory or reproductive behaviour.

Toward the middle of the year, February and March exhibit moderate catch levels that may indicate early-year fishing activity, while April through June and July show low or zero catches, which may suggest a reduction in the fishing season for this species during these months or simply a lower abundance of *Sphyrna lewini*. During 2021, we caught everything from one year's season to the other of nearly two years; in 2022, however, we only had catches recorded in February (demonstrating that fishing patterns can vary). However, the fact that fishers would land their catch in other locations, such as Tanjung Luar Lombok, due to price differentiation clouds a clear judgment of when the season is. The western season does seem linked to increased catch rates; however, as indicated by this and previous studies [9], targeted management strategies may be an essential step forward to managing populations that account for such temporal and seasonal variation. This data indicates that ecological dynamics, including migrations and reproduction, are critical to consider in achieving sustainable shark fisheries practices and reducing the threat of overfishing on a population-wide level for the critically endangered *Sphyrna lewini* within Muncar. For details see Figure 7.

Fig. 7. Seasonal Shark Catch (2020-2023)

Figure 8 shows the annual percentage of Scalloped Hammerhead sharks (*Sphyrna lewini*) landed in Muncar fish markets compared to all shark species. The rate of *Sphyrna lewini* landings oscillated from 14% in 2020 through a high of 11% in 2021 and back down to 9% in 2022 over the last four years. But that catch percentage improved to 14% in 2023. Since *Sphyrna lewini* is regularly part of the total catch but only present at less than 15% throughout all years, this shark species represents a fraction of the total shark species fished, which includes 58 different species. When compared to the research conducted by [6] in 2020, which identified 46 shark species based on landing data, an additional 12 new shark species were documented between 2021 and 2023.

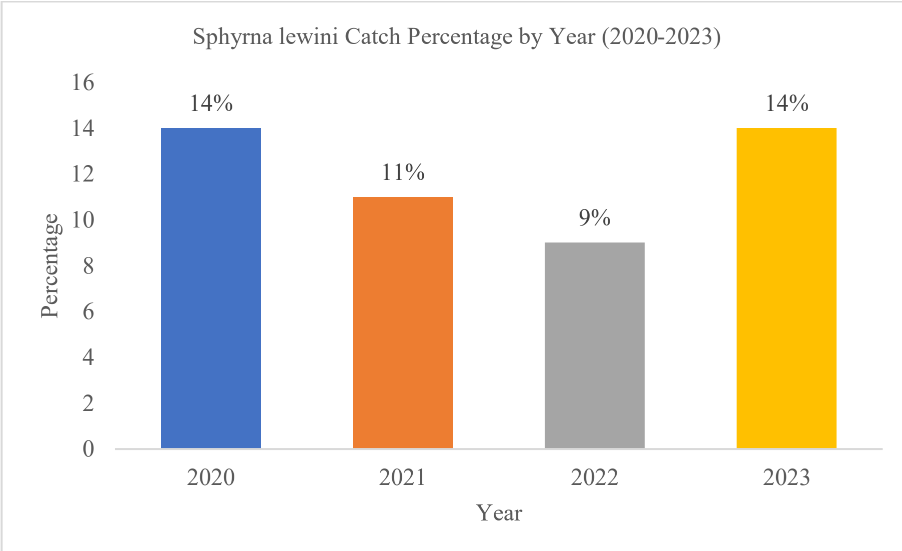


Fig. 8. The proportion of total catch of *Spyrna lewini* (2020-2023) compared to all shark species

3.2 Discussion

Our findings highlight the high proportion of juvenile and sub-adult *Sphyrna lewini* caught in small-scale fisheries, particularly using gillnets and longlines. This is a major concern, as *Sphyrna lewini* is listed as Critically Endangered on the IUCN Red List due to overfishing, primarily from bycatch in artisanal and commercial fisheries [22]. The juvenile mortality identified in our study could further exacerbate population declines by hindering the species' recovery potential, as *Sphyrna lewini* has slow reproductive rates [23,24]. Our research aligns with global conservation initiatives like the Convention on International Trade in Endangered Species (CITES), which includes *Sphyrna lewini* under Appendix II to regulate international trade and prevent overexploitation. However, trade restrictions alone are insufficient without improvements in fishing practices at the local level, as these species continue to face high mortality in non-target fisheries [9].

Based on the catch composition and fishing methods in Muncar, we recommend targeted changes to fishing practices, such as incorporating bycatch reduction devices (BRDs) and time-area closures. Studies have shown that BRDs, such as escape panels in gillnets and circle hooks in longlines, significantly reduce the bycatch of endangered species, including *Sphyrna lewini* [25]. Time-area closures, which prevent fishing during peak pupping seasons, would further support population recovery, as *Sphyrna lewini* tend to congregate in nursery areas [24].

For example, protected areas and seasonal closures have proven successful in reducing elasmobranch bycatch [26–28]. Adopting similar practices in Indonesia could complement the existing National Plan of Action for Sharks and Rays (NPOA-Sharks), which aims to promote sustainable shark fisheries and the conservation of endangered species [14]. Muncar's shark fishery shares similarities with other small-scale fisheries in Indonesia, particularly in terms of species composition, fishing gear, and the challenges associated with bycatch of endangered sharks. For example, research conducted in Banda Aceh and Sibolga-North Sumatra, and has documented significant catches of *Sphyrna lewini* and *Carcharhinus longimanus*, often involving juveniles [29]. Similar to Muncar, gillnets and longlines are the primary gear used, contributing to high bycatch rates of endangered shark species [3].

Additionally, a study in Cilacap, Central Java, and Tanjung Luar, Lombok reported similar challenges, with high landings of juvenile sharks, including *Sphyrna lewini* [30]. These findings emphasize the need for gear modifications and stricter enforcement of fishing regulations in shark nursery areas across Indonesia. Muncar, like other regions, suffers from limited enforcement and compliance with Indonesia's National Plan of Action for Sharks and Rays (NPOA-Sharks), which calls for the protection of endangered species like *Sphyrna lewini* [14].

When compared globally, Muncar's shark fishery reflects patterns observed in other developing countries with small-scale fisheries. In Ecuador, for example, studies have shown that the artisanal shark fishery also targets juvenile sharks, with high bycatch of endangered hammerheads (*Sphyrna spp.*) due to gillnet use [31]. Both regions face similar challenges: the reliance on shark fisheries for local livelihoods, lack of alternative income sources, and weak enforcement of conservation policies. However, Ecuador has made progress in establishing time-area closures and marine protected areas, which have contributed to declines in hammerhead shark bycatch in some regions [28]. Such measures could be adapted to Muncar to reduce the pressure on endangered shark populations.

Similarly, in West Africa, small-scale shark fisheries have documented high rates of bycatch for species like *Sphyrna lewini* and *Carcharhinus spp.*, with gillnets being a major culprit [32]. The West African region has seen some success through community-based management approaches and gear modifications, such as the introduction of escape panels and the prohibition of fishing in certain nursery grounds[32]. Muncar could benefit from adopting these community-driven approaches, which have helped reduce shark bycatch and improve compliance with conservation measures in West Africa.

3.2.1 Ecological Impact of Losing Sphyrna lewini

The decline or loss of Sphyrna lewini from marine ecosystems can trigger "trophic cascades," wherein changes at the apex of the food chain cause ripple effects throughout the ecosystem[1]. For instance, a reduction in Sphyrna lewini populations may lead to an increase in smaller predatory fish, which could then overexploit prey species such as herbivorous fish. Herbivorous fish are crucial for regulating algae on coral reefs, and their depletion could result in algal overgrowth, which inhibits coral growth and diminishes reef resilience [33].

4 Conclusion

The Sphyrnidae family represents the second-largest shark landing in Muncar, with 1,098 individuals recorded over four years. To mitigate the risks associated with overexploitation of these species, several steps are recommended. First, implementing catch limits or restrictions on critically endangered species like the scalloped hammerhead (*Sphyrna lewini*) is essential. Second, improved monitoring of landings and stricter enforcement of fishing regulations, particularly for species under international protection (e.g., CITES-listed species), are necessary. Third, promoting sustainable fishing practices through gear modifications to reduce bycatch and introducing seasonal fishing closures during peak reproductive periods can help protect vulnerable species. The high number of *Sphyrnidae* landings in Muncar, particularly the endangered *Sphyrna lewini*, underscores the urgent need for improved management and conservation efforts.

By implementing stricter regulations, promoting sustainable fishing, and protecting critical life stages, these steps can contribute to the long-term sustainability of shark populations in the region and mitigate the threat of overexploitation.

Future research should focus on refining methods to assess population dynamics and reproductive biology in key regions, particularly in critical nursery and breeding grounds.

Policy development should prioritize the expansion of Marine Protected Areas (MPAs), the implementation of seasonal fishing bans, and the enhancement of international cooperation to enforce shark conservation regulations. Additionally, participatory approaches involving local fishing communities are essential to ensure the effectiveness of conservation measures and the long-term sustainability of shark populations.

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