

Exploring social-ecological dynamics in an important shark and ray area: a case study of small-scale fisheries in Sumbawa, Indonesia

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Abstract. Small-scale fisheries (SSFs) in Indonesia often intersect with ecologically sensitive areas, necessitating integrated approaches to conservation and governance. This study investigates the social-ecological dynamics of SSFs in Lunyuk, Southern Sumbawa—an area designated as an Important Shark and Ray Area (ISRA). Through 224 days of field-based landing observations and stakeholder interviews, we documented 513 elasmobranch individuals, with 64.1% identified as Critically Endangered and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)-listed species, notably *Sphyrna lewini* and *Rhynchobatus australiae*. Alarming, most individuals were below known maturity sizes, and females dominated the catch, highlighting acute conservation concerns. Social Network Analysis (SNA) revealed a moderately centralized but locally anchored governance structure, with fishers, Non-Governmental Organizations (NGOs), and village leaders acting as key nodes. However, vertical linkages to higher regulatory institutions remained weak, and market actors were structurally peripheral. Qualitative analysis underscored intergenerational identity, economic dependency, and cultural legacy as primary motivators sustaining fishing practices, even under ecological stress. These findings suggest that community-led co-management strategies that align conservation interventions with socio-economic and cultural realities to protect the threatened shark and ray species and local livelihoods.

1. Introduction

Small-scale fisheries (SSFs) are an essential source of livelihoods and food security globally, with multidimensional contributions to sustainable development [1]. SSFs are often embedded in socio-economic and cultural traditions, while also intersecting with conservation priorities - particularly when unselective fishing activities overlap with critical habitats of threatened species [2,3]. In Indonesia, reconciling the social and economic contributions of SSFs with elasmobranch conservation is particularly challenging [4]. Elasmobranchs are amongst the world's most



threatened species groups, primarily due to overfishing, which is exacerbated by their slow life histories and low fecundity, which collectively constrain their recovery potential under sustained harvest pressure [5,6]. Preventing population declines and extinctions of elasmobranchs in Indonesia will require reductions in fishing mortality, yet many elasmobranchs are captured and retained in SSFs, forming a part of coastal livelihood and food security strategies.

The Lunyuk coastal waters, located in Lunyuk District, Southern Sumbawa, West Nusa Tenggara Province, represent a critical habitat for elasmobranch species, particularly sharks and rays [7]. Based on fisher-reported observations [8], juvenile individuals are frequently captured in this area, suggesting that these waters serve as a nursery ground—an essential developmental habitat—for shark and ray populations in Indonesia.

To address these conservation risks of elasmobranch, a socio-ecological approach is required—one approach that integrates biological data from landings with insights from human behavior, institutional norms, and governance systems [9]. In many SSFs context, fishers' decisions are shaped not merely by market forces but also by kinship, custom, and identity. These social dimensions influence compliance, gear selection, and responsiveness to conservation interventions to protect sharks and rays [4,9].

This study explores these dynamics in Lunyuk—an area that is globally recognized as an Important Shark and Ray Area (ISRA) but is also a socio-economically important fishing grounds for SSFs and coastal communities in Sumbawa. By combining ecological sampling and stakeholder network mapping, this research aims to understand species composition trends and governance structures to inform context-specific, community-led fisheries management.

2. Methods

2.1 Study site

This study was conducted in Lunyuk District, located in southern Sumbawa, West Nusa Tenggara Province, Indonesia, with a primary focus on the villages of Emang Lestari and Perung (Figure 1). Southern Sumbawa has recently gained recognition for its global conservation significance due to the presence of critical habitat for threatened elasmobranch species. The area has been designated as the Southern Sumbawa Important Shark and Ray Area (ISRA) by the International Union for Conservation of Nature (IUCN), based on the consistent occurrence of species from the families *Sphyrnidae*, *Narcinidae*, *Rhinobatidae*, and *Rhinidae* within depths of 0–100 meters [7]. The region features a narrow continental shelf characterized by a mix of sandy, muddy, and rocky substrates. Additionally, this study site is crucial due to several rivers discharge into this coastal zone, contributing nutrient inputs that enhance local marine productivity.

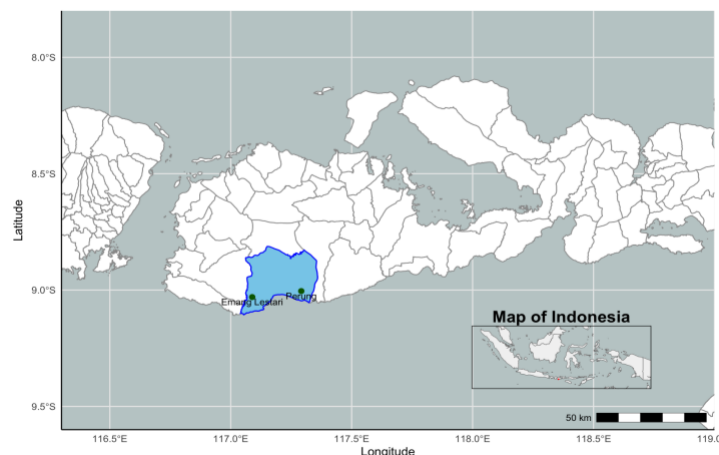


Figure 1. Map showing the study area in Lunyuk, Southern Sumbawa, Indonesia.

2.2 Data collection

2.2.1 Ecological data

Shark and ray landings data were collected in 2024 through a collaborative effort involving trained local enumerators from *Yayasan Kebersamaan Untuk Lautan*¹. Over the course of 224 sampling days, from January 2024 to December 2024, a total of 307 fishing trips were recorded. During each landing event, ecological data were obtained for individual elasmobranch species, including species identification, fork length (FL), total length (TL), and sex [10].

2.2.2 Socio-economic data

Socio-economic data were collected through semi-structured interviews and Focus Group Discussions (FGDs) involving key stakeholders, including fishers, traders/middlemen, local government representatives, and community members. A total of 31 fishers from Emang Lestari and Perung villages were purposively selected as respondents based on their fishing gear types [4]. Specifically, fishers using gillnets and longlines—gear types known for their high likelihood of capturing sharks and rays—were prioritized for inclusion. Most respondents employed multiple fishing gears, including handlines, but only those operating gillnets and/or longlines were interviewed because these are the gears known to capture the most elasmobranchs [8].

The survey gathered information on socio-demographic characteristics and variables relevant to elasmobranch fisheries, such as operational costs, and market dynamics, while the FGDs gathered information on catch utilizations, fishery actor interactions, and local management practices. This gear-targeted, stakeholder-informed approach provided a hed understanding of the socio-economic drivers and governance challenges associated with elasmobranch bycatch in Southern Sumbawa [4].

2.3 Data analysis

Ecological data—including species composition, fork length (FL), total length (TL), and sex— were analyzed using descriptive statistics to summarize total retained catches, size distributions, and catch frequency. Conservation status was determined by referencing the IUCN Red List of Threatened Species. All analyses were conducted in RStudio Version 2024.12.0+467, using a suite of packages for data wrangling and visualization such as *dplyr*, *tidyr*, *ggplot2*, *ggrepel*, *wordcloud*, *TColorBrewer*, *tm*, and *networkD3*.

Socio-economic data were analyzed using a mixed-methods approach. Quantitative responses were processed using descriptive statistics to assess demographic characteristics, gear usage, and operational costs. Qualitative data from semi-structured interviews and Focus Group Discussions (FGDs) were analyzed through situational and thematic analysis [11]. Thematic coding was used to identify key issues, and frequently mentioned terms were visualized using word clouds. To assess stakeholder dynamics, Social Network Analysis (SNA) was conducted to visualize the relationships among fishers, traders, and governance actors. All socio-economic research involving human participants was reviewed and approved by the Central University Research Ethics Committee at the senior authors institute, ensuring that ethical standards for informed consent, confidentiality, and participant welfare were met throughout the study.

3. Results and discussions

3.1 Results

3.1.1 Fishery characteristics

The fisheries operating from Emang Lestari and Perung villages are predominantly composed of small-scale fishers, who typically conduct daily fishing trips lasting 4 to 6 hours. These fishers operate small outboard-powered vessels ranging from 4 to 10 meters in length (mean: 6.5 m),

¹*Yayasan Kebersamaan Untuk Lautan (KUL)*, Indonesian nonprofit foundation dedicated to protecting marine ecosystems and supporting coastal livelihoods, legal number AHU-0011740.AH.01.04. Year 2023 (Ministry of Law and Human Rights, Republic of Indonesia), Badung, Bali, <https://kebersamaan-lautan.org>

equipped with engines ranging from 6.5-10.0 horsepower (mean: 7.75 HP) (Figure 2).



Figure 2. Typical small outboard-powered vessels in Lunyuk

A total of 60 vessels were recorded to operate from the study villages, all employing multi-gear fishing practices. Handlines were the most commonly used gear, present on 59 vessels (98.3%), followed by longlines on 32 vessels (53.3%) and gillnets on 16 vessels (26.7%). Gear selection was often adjusted according to seasonality, target species, and fishing locations.

Fishers reported targeting a diverse range of pelagic and demersal finfish species. Commonly targeted pelagic species included *Euthynnus affinis*, *Spratelloides gracilis*, *Scomberomorus commerson*, *Caranx ignobilis*, *Thunnus* spp., and *Rastrelliger brachysoma*. Demersal species of economic importance included *Gerres* spp., *Lutjanus* spp., *Caranx ignobilis*, *Sardinella lemuru*, and *Epinephelus* spp. This species diversity reflects the multi-species and multi-gear nature of the fishery in Southern Sumbawa's coastal waters.

3.1.2 Elasmobranch landings

To provide an overview of the conservation status and species composition of elasmobranchs retained in Lunyuk SSFs. Figure 3 presents the proportional distribution of elasmobranch landings by conservation status (Figure 3a) and the corresponding species composition of landings in 2024 (Figure 3b).

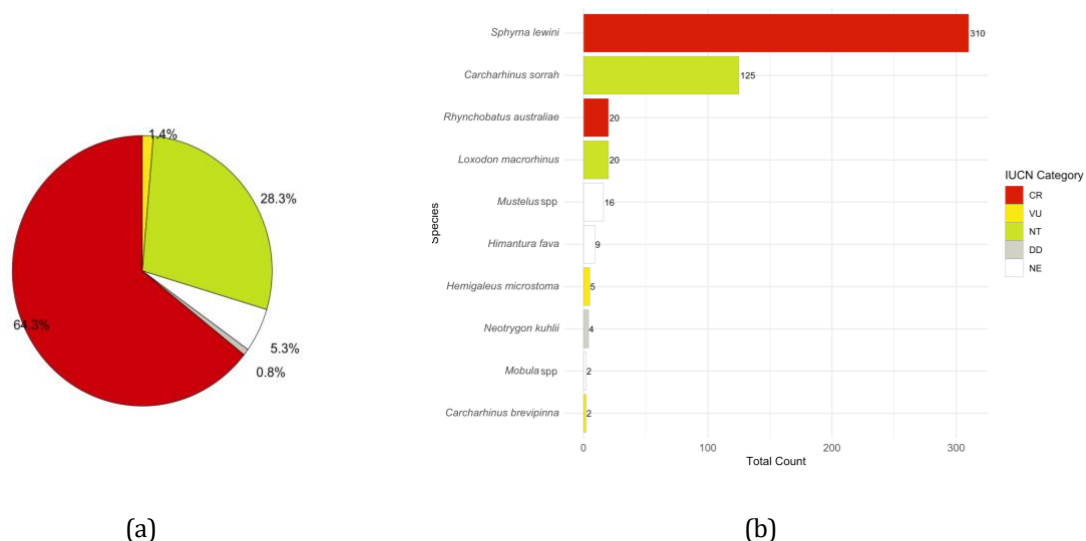


Figure 3. Proportion of elasmobranch (a) and composition of elasmobranch landings in 2024 (b), color-coded by IUCN Conservation

During the study period, a total of 513 individual elasmobranchs were recorded as retained catch by fishers from Emang Lestari and Perung. Of the recorded elasmobranchs (64.3%) were classified as Critically Endangered (CR), primarily due to the high catch of *Sphyrna lewini*. Near Threatened (NT) species accounted for 28.3% of total elasmobranch catches, while Data Deficient (DD) and Not Evaluated (NE) species comprised 0.8% and 5.3%, respectively. Only a small fraction (1.4%) of the catch belonged to species listed as Vulnerable (VU) (Figure 3a).

Species composition was dominated by *Sphyrna lewini*, which accounted for 310 individuals, followed by *Carcharhinus sorrah* (125 individuals), *Rhynchobatus australiae* and *Loxodon macrorhinus* (20 individuals each), and *Mustelus* spp. (16 individuals). Less frequently encountered species included *Himantura fava* (9), *Hemigaleus microstoma* (5), *Neotrygon kuhlii* (4), *Mobula* spp. (2), and *Carcharhinus brevipinna* (2) (Figure 3b).

The sex composition of the CR species, *Rhynchobatus australiae* and *Sphyrna lewini*, revealed a predominance of females in the landings. In *Rhynchobatus australiae*, females constituted 55.0% of the individuals recorded, while males accounted for 45.0%. A more pronounced female-biased ratio was observed in *Sphyrna lewini*, with females comprising 61.6% of the catch and males 38.4%.

3.1.3 Total length distribution of the elasmobranch landings

The size distribution of *Rhynchobatus australiae* and *Sphyrna lewini* individuals landed during the study revealed a concerning dominance of immature species (Figure 4). For *Rhynchobatus australiae*, the majority of individuals measured below the species' reported size at maturity of 155 cm, with total lengths ranging from 47 and 157 cm. Similarly, for *Sphyrna lewini*, the size distribution was strongly skewed towards smaller individuals, with most species below the maturity threshold of 210.5 cm. The total length of *Sphyrna lewini* ranged between 48 and 154 cm (Figure 4).

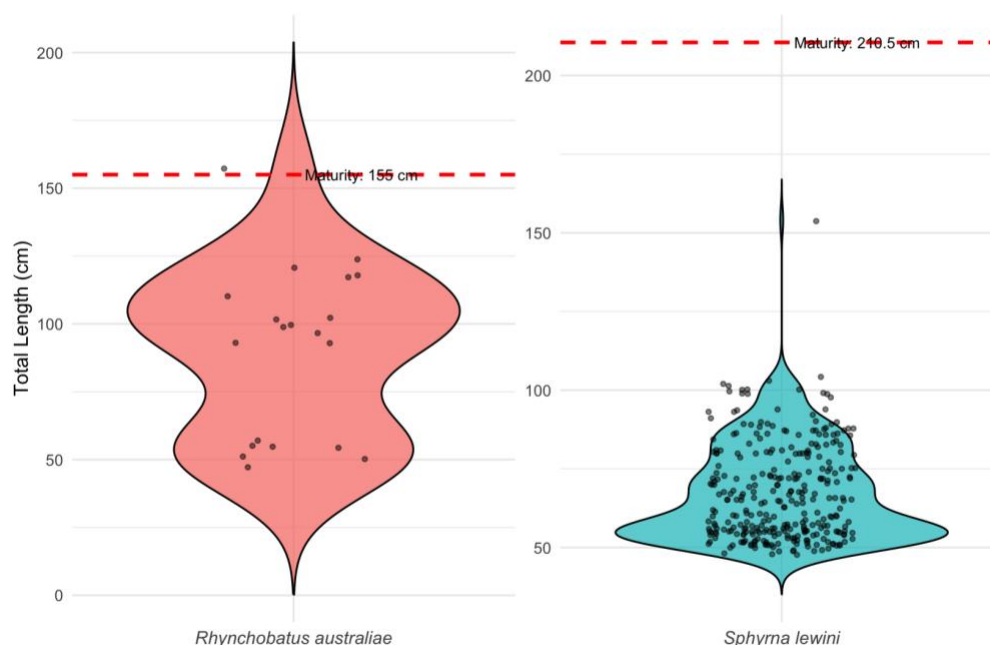


Figure 4. Total length (cm) distributions of *Rhynchobatus australiae* and *Sphyrna lewini* landed in 2024, shown as violin plots. Black dots represent individual observations, violin width indicates data density, and red dashed lines denote estimated maturity lengths (*Rhynchobatus australiae*: 155 cm; *Sphyrna lewini*: 210.5 cm)

3.1.4 Catch utilization and fishing income

Catch utilization among SSFs in the study area demonstrates a strong market-driven pattern. According to focus group discussion and interview data, most catches—across all species—are sold rather than consumed at the household level. Based on reported catch utilization, fishers estimated that, on average, roughly 85 - 90% of their total catch is sold, while only 10 - 15% is retained for household consumption (Figure 5). These reported patterns of utilization were largely consistent across target finfish and elasmobranchs.

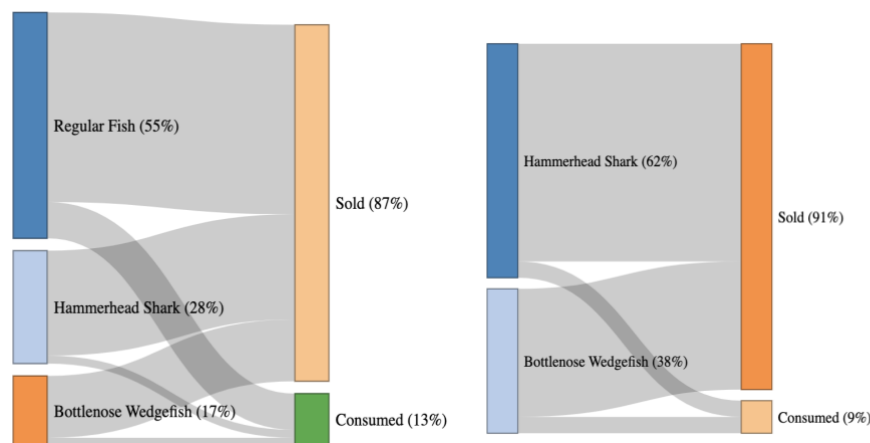


Figure 5. Fish catch utilization by small-scale fishers in Lunyuk. Sankey diagrams show the proportion of total and elasmobranch catches that were sold or consumed, with flow widths representing relative proportions

Monthly income among small-scale fishers from interview data was highly variable, with most fishers earning below 2 million IDR per month (Figure 6). Income distribution is left-skewed with a long tail, indicating that while a few fishers earn up to 6 million IDR, the majority earn much less. The density peaks between 1 and 2 million IDR, suggesting this is the most common income range (Figure 6).

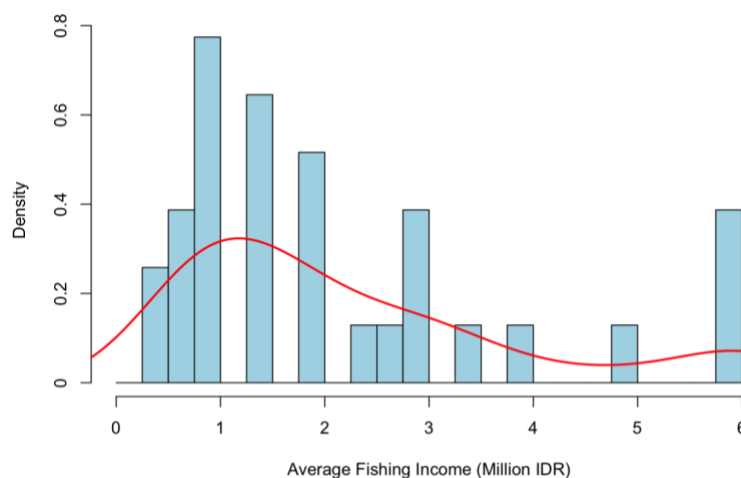


Figure 6. Distribution of average fishing income among small-scale fishers in Lunyuk. The histogram shows the frequency distribution of average fishing income (in million IDR), while the red line represents the kernel density estimate illustrating the overall income distribution pattern

3.1.5 Fishing driven factor

Fishers' motivations for engaging in fishing activities reflect a complex interplay of socio-cultural and economic drivers. As depicted in the word cloud (Figure 7), the most salient themes include intergenerational continuity, livelihood dependence, and personal passion.

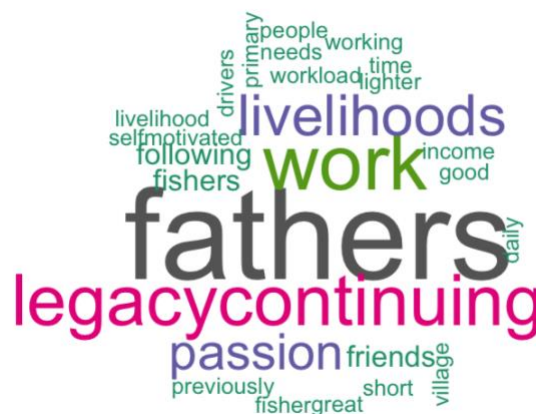


Figure 7. Key motivations for fishing among small-scale fishers in Lunyuk- illustrated using Wordcloud

The term “*fathers*” emerged as the most prominent word mentioned during interviews, indicating a strong inheritance of fishing practices from previous generations. Words such as “*legacy*,” “*continuing*,” and “*following*” further reinforce the idea that fishing is not merely an economic activity, but a familial and cultural tradition. This finding highlights the importance of identity and lineage in shaping fishers' occupational choices.

The second major theme centers around livelihood dependency, with frequent mentions of “*work*,” “*livelihood*,” and “*income*.” These responses confirm that fishing remains the primary or sole source of income for many households, especially in rural coastal areas with limited alternative employment opportunities. Additionally, emotional and self-driven factors were observed, as indicated by terms such as “*passion*,” “*self-motivated*,” and “*friends*.” These words suggest that beyond necessity, some fishers are personally invested in fishing, valuing it as a meaningful or satisfying activity. Collectively, these motivational drivers emphasize that interventions aimed at conservation and livelihood transformation must account for both economic reliance and the deep cultural embeddedness of fishing practices.

3.1.6 Actor interactions related to sharks and rays

The social network analysis (SNA) revealed a moderately centralized governance structure in Lunyuk, with distinct clusters of actors from community, market/support groups, local institutions, government, and external sectors (Figure 8). Fishers, NGOs, and the Fisher's group leader emerged as key nodes in terms of degree and eigenvector centrality, indicating their central roles in local coordination, communication, and influence. The Fisher's group leader exhibited the highest eigenvector centrality (1.00), reflecting its prominent structural position in influencing actors with similarly high centralities.

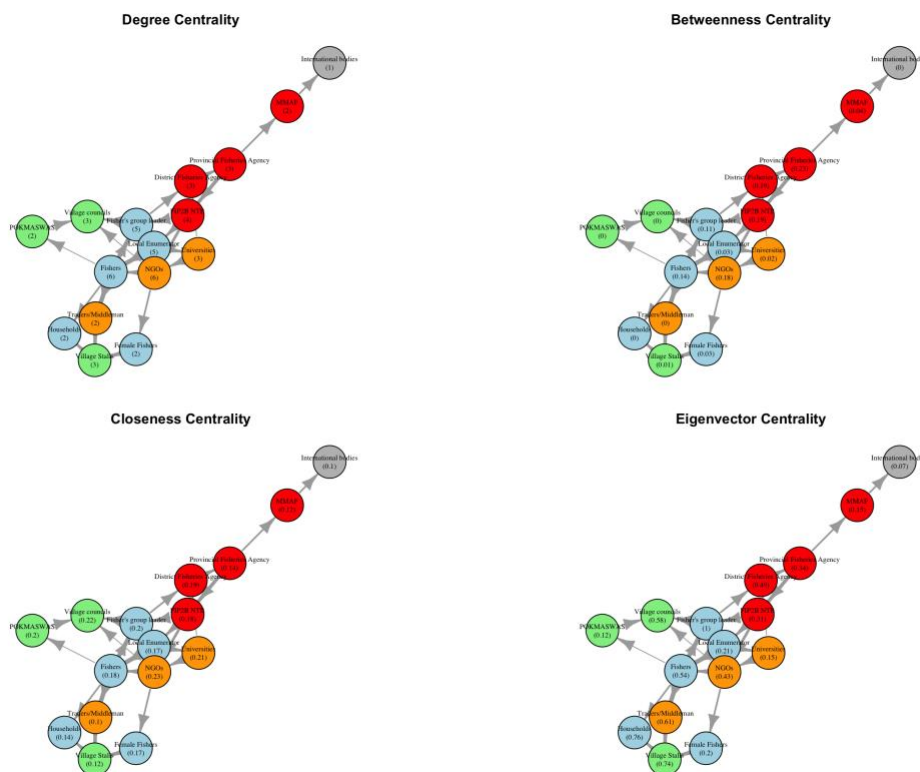


Figure 8. Actor interaction network in the Lunyuk SSFs governance system. The network is visualized using degree, betweenness, closeness, and eigenvector centrality (top left to bottom right). Node size represents the respective centrality value, and arrows indicate the direction of interactions. Node colors denote actor categories: light blue (community actors), light green (local institutions), orange (support and market actors), red (government actors), and gray = (external actors)

The Provincial Fisheries Agency displayed the highest betweenness centrality (0.23), acting as a crucial bridging organization that connects grassroots actors with higher levels of governance. This suggests its strategic role in facilitating policy flow, cross-level engagement, and governance integration across vertical institutional scales. Households and village stalls, while less central in terms of direct connections (degree), demonstrated high eigenvector centrality (0.76 and 0.74, respectively), reflecting their importance through indirect influence within the network. Their close ties to central actors such as fishers and NGOs indicate that they play a vital role in reinforcing information dissemination and resource flows (Figure 8).

Meanwhile, external actors like international bodies and MMAF (Ministry of Marine Affairs and Fisheries) were peripheral, with low degrees and centrality scores, implying limited direct interaction with local stakeholders. Similarly, market actors such as traders/middlemen and female fishers held marginal structural positions but may still hold contextual or economic influence not captured through structural metrics alone. Overall, the network indicates a hybrid governance model where localized actors (e.g., fishers, NGOs, village leaders) are structurally embedded alongside governmental institutions. This structure emphasizes the importance of strengthening vertical linkages and enhancing the participation of peripheral yet relevant actors to support inclusive and adaptive governance mechanisms in small-scale fisheries (Figure 8).

3.2 Discussions

This study provides an overview of the ecological and social characteristics of small-scale fisheries (SSFs) in Lunyuk, Southern Sumbawa, which overlap with a globally recognized Important Shark and ray Area (ISRA). Landings data indicates the dominance of Critically Endangered (CR) species,

where, of all the landed sharks and rays, 64.1% was identified as CR species, and CITES Appendix II lists species, namely *Sphyrna lewini* (scalloped hammerhead) and *Rhynchobatus australiae* (bottlenose wedgefish). This high occurrence of CR species highlights the need to ensure sustainable management SSFs in the Southern Sumbawa ISRA. A particularly concerning finding is that most *Sphyrna lewini* (scalloped hammerhead) and *Rhynchobatus australiae* (bottlenose wedgefish) caught were below the length of maturity for both species [12,13]. This suggests that there is an intense fishing pressure on juvenile populations, which may prevent recruitment and future breeding potential. Moreover, females also dominate the catch, which can amplify pressure on reproductivity and further reduce population recovery potential [14,15].

Despite these ecological risks, fishers in this area continue to undertake their fishing practices, driven by socio-economic and cultural factors. Fishers in Lunyuk rely on marine resources for their livelihoods, as can be seen that 87% of total fish catch being sold rather than consumed, yet the fishers are not wealthy, with the majority of fishers earning less than 2 million rupiah per month from fishing. The average monthly income in the Sumbawa region is approximately USD 55.8 (equivalent to USD 1.86 per day), which is below minimum average net income per month in West Nusa Tenggara Province ~ USD 2.39 per day as defined by Badan Pusat Statistik in 2024. This indicates that a significant portion of the population is living in conditions of poverty, with limited access to basic needs and financial resilience. However, motivations for fishing extend beyond economics. The word cloud analysis revealed that intergenerational identity, legacy, and personal passion play roles in shaping fishers' behaviour. Words like "fathers", "legacy", and "continuing" were frequently stated, suggesting that fishing is perceived as a family tradition and cultural heritage, which aligns with results from other similar studies of SSFs in Indonesia [16].

An analysis of actor interactions related to sharks and rays in Lunyuk's SSFs, through Social Network Analysis (SNA), reveals a moderately centralized yet strongly localized governance system. Within this network, fisher's group leaders, non-governmental organizations (NGOs), and fishers themselves occupy central coordinating positions, indicating a robust structure of local engagement and bottom-up decision-making. Such a configuration reflects the presence of embedded governance practices conducive to context-specific resource management. However, the network is marked by weak vertical linkages to national and international governance institutions, including regulatory agencies and policy bodies. Additionally, despite their substantial economic influence, market actors remain structurally peripheral within the network, suggesting limited institutional interaction with core governance mechanisms. This structural disconnect may hinder the effective transmission of policy directives, technical support, and enforcement capacity from higher governance levels to local stakeholders, which may be one reason why Critically Endangered and CITES-listed species continue to dominate catches. Furthermore, the peripheral role of market actors reduces opportunities for integrating traceability systems, sustainability certifications, or price-based incentives that could otherwise align market demand with conservation objectives. Strengthening these linkages could enhance both top-down regulatory coherence and bottom-up compliance through market leverage and institutional support. Households and village stalls have high influence through strong connections to key players, suggesting that engaging these grassroots actors can amplify conservation and livelihood initiatives.

4. Conclusion

The findings from this study call for the urgent development of localized, culturally sensitive fisheries management frameworks in Southern Sumbawa's Important Shark and Ray Area (ISRA). The high presence of Critically Endangered juvenile sharks and rays in landings—especially *Sphyrna lewini* and *Rhynchobatus australiae*—underscores unsustainable fishing practices that threaten species recovery and long-term fishery viability. Management must go beyond ecological

considerations to address deep-rooted socio-economic dependencies and intergenerational fishing identities. Key steps include strengthening vertical governance linkages to improve policy coherence and enforcement, integrating market actors into co-management structures for traceability and incentives, and empowering central grassroots actors—such as fisher groups, NGOs, and local leaders—to co-design community-based solutions. Targeted livelihood diversification, participatory monitoring, and gear-specific regulations should be coupled with conservation education that respects cultural traditions while promoting sustainability.

Acknowledgements

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References

- [1] Basurto X *et al* 2025 *Nature* **637** 875–84
- [2] Calò A, Franco AD, Quattrocchi F, Dimitriadis C, Ventura P, Milazzo M and Guidetti P 2022 *Fish Fish* **23** 1299–1312
- [3] Booth H, Squires D, Milner-Gulland E J *Ocean Coast. Manag.* **182** 104994
- [4] Booth H, Ichsan M, Hermansyah R F, Rohmah L N, Naira K B, Adrianto L, Milner-Gulland E J 2023 *People Nat.* **5** 968–980
- [5] Dulvy N K *et al* 2021 *Curr. Biol.* **31** 4773–4787
- [6] Pacoureaux N *et al* 2021 *Nature* **589**, 567–571
- [7] IUCN SSC Shark Specialist Group 2024 *Southern Sumbawa ISRA Factsheet* (Dubai: IUCN SSC Shark Specialist Group) <https://sharkrayareas.org/wp-content/uploads/isra-factsheets/09Asia/Southern-Sumbawa-09Asia.pdf> (accessed 4 August 2025)
- [8] Simeon B M, Muttaqin E, Ichsan M, Tarigan S, Hernawati and Yulianto I 2018 *Laporan Teknis: Kajian Habitat Penting Hiu dan Pari di Lunyuk, Sumbawa, Provinsi Nusa Tenggara Barat* (Bogor, Indonesia: Wildlife Conservation Society–Indonesia Program) https://www.researchgate.net/publication/348785213_kajian_habitat_penting_hiu_dan_pari_di_lunyuk_sumbawa_provinsi_nusa_tenggara_barat_wildlife_conservation_society_indonesia_program_2018 (accessed 4 August 2025)
- [9] Booth H, Ramdhan M S, Hafizh A, Wongsopatty K, Mourato S, Pienkowski T, Adrinato L, and Milner-Gulland E J 2023 *Biol. Conserv.* **277** 109821
- [10] Training Department 2007 *A Manual for Fish Landing Data Management System* (Bangkok: Southeast Asian Fisheries Development Center) <http://hdl.handle.net/20.500.12067/654> (accessed 4 August 2025)
- [11] Newing H, Eagle C, Puri R K and Watson C 2011 *Conducting Research in Conservation* (Oxfordshire: Routledge)
- [12] Kyne P M, Rigby C L, Dharmadi and Jabado R W 2019 *Rhynchobatus australiae* IUCN Red List Threat. Species e.T41853A68643043 <https://doi.org/10.2305/IUCN.UK.2019-2.RLTS.T41853A68643043.en> (accessed 4 August 2025)
- [13] Rigby C L *et al* 2019 *Sphyrna lewini* IUCN Red List Threat. Species e.T39385A2918526 <https://www.iucnredlist.org/species/39385/2918526> (accessed 4 August 2025)
- [14] Drymon J M, Dedman S, Froeschke J T, Seubert E A, Jefferson A E, Kroetz A M, Mareska J F and Powers S P 2020 *Front. Mar. Sci.* **7** 35
- [15] Green M E *et al* 2018 *Endang. Species Res.* **37** 45–54
- [16] Booth H, Pooley S, Clements T, Putra M I H, Lestari W P, Lewis S, Warwick L and Milner-Gulland E J 2020 *Glob. Ecol. Conserv.* **22** e00953