Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(2): 885 – 895 (2025)
www.ejabf.journals.ekb.eg

Length Distribution and Abundance of Sharks and Relationship with Temperature in the Bali Strait Waters

Michelle Levina[1, 2]*, Sunarto[3], Wahyuniar Pamungkas[3], Mochamad Rudyansyah Ismail [3] and Muhammad Ghozaly Salim[4]

[1]Marine Science Program, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Jatinangor, Sumedang, 45363
[2]Marine Conservation Program, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Jatinangor, Sumedang, 45363
[3]Departmen of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Jatinangor, Sumedang, 45363
[4]Mobula Project Indonesia, Muncar, Banyuwangi, 68472
***Corresponding Author: michelle20003@mail.unpad.ac.id**

ARTICLE INFO
Article History:
Received: Sep. 9, 2024
Accepted: Feb. 17, 2024
Online: March 18, 2025

Keywords:
Shark by-catch,
Sea surface temperature,
Bali Strait,
Conservation,
Fisheries management

ABSTRACT
This study aimed to analyze the composition, size distribution, sex ratios, and the influence of sea surface temperature (SST) on shark by-catch in the Bali Strait. Data were collected at Brak Muncar Fish Landing Port, Banyuwangi, from March 2023 to February 2024, using a census method for three dominant species: *Alopias pelagicus*, *Carcharhinus melanopterus*, and *Atelomycterus marmoratus*. Species identification, total length (TL) measurements, and sex determination followed scientific protocols, while SST data were processed using IDW interpolation in QGIS. A simple linear regression analysis tested the relationship between SST and catch abundance. A total of 299 shark individuals were recorded, dominated by *A. marmoratus* (140 individuals) and *C. melanopterus* (131 individuals). Most catches comprised juveniles, particularly *C. melanopterus* (45–56.6cm) and *A. pelagicus* (137.8–172.7cm), indicating exploitation of immature populations. A balanced sex ratio (1:1) was observed across all species. SST significantly influenced *C. melanopterus* catches (R = 0.650), moderately affected *A. pelagicus* (R = 0.496), and had negligible impact on *A. marmoratus* (R = 0.085) due to its dependency on coral reef habitats. Policy implications emphasize the need for strict by-catch reduction regulations, temporary no-catch zones in breeding areas, and conservation policy harmonization aligned with IUCN/CITES statuses. Recommendations include training fishers in selective techniques, establishing community-based monitoring systems, and integrating ecological data into science-based catch quotas. Further studies should focus on long-term monitoring, genetic population analyses, and interdisciplinary approaches to support sustainable shark fisheries in Indonesia.

INTRODUCTION

Sharks have become a significant commodity for Indonesian small-scale fishers **(Eko Wibowo & Ika Joesidawati, 2024)**. Shark fishing is driven by their high economic value, particularly for their fins and liver oil **(Sulaiman & Triharyuni, 2021)**. Shark fins are commonly consumed or used in cosmetics, while their livers are processed for oil. Indonesia hosts at least 117 shark species across 25 genera, making it the world's largest shark producer, contributing 16.8% of global shark catches **(Wibowo & Joesidawati, 2023)**. Over recent decades, shark populations have declined due to targeted and by-catch fishing **(Carr *et al.*, 2013)**. Numerous studies highlight concerns about this decline, as the loss of apex predators disrupts aquatic ecosystem balance **(Kamil *et al*., 2023)**.

Sharks in Indonesian waters play a critical ecological role as apex predators, maintaining food chain stability by preying on aged, diseased, or weaker fish **(Motivarash *et al.*, 2020)**. Their absence could cascade through entire trophic networks. Shark distribution is influenced by abiotic factors, with temperature being a key driver **(Heupel & Simpfendorfer, 2011)**. Seasonal temperature variations affect their spatial distribution, as species exhibit distinct thermal adaptations and optimal ranges **(Schlaff *et al*., 2014)**.

The Bali Strait, Indonesia, supports high fishery productivity, yielding an average of 100 tons of fish annually **(KKP, 2011)**. Pelagic species such as mackerel, scad, and sardines dominate catches **(Huda & Rini, 2021)**. Sharks are also landed here as bycatch and traded at Brak Muncar Fish Landing Port (TPI) in Banyuwangi. This study examined the size distribution, catch abundance, and temperature-related patterns of three frequently caught shark species in the Bali Strait: *Alopias pelagicus*, *Carcharhinus melanopterus*, and *Atelomycterus marmoratus*. Data were collected on size classes, sex ratios, and conservation status. *A. pelagicus* is classified as Endangered (IUCN) and listed in CITES Appendix II; *C. melanopterus* is Vulnerable (IUCN) and CITES Appendix II; while *A. marmoratus* is Near Threatened (IUCN) and unlisted under CITES. This research provides critical insights for sustainable fisheries management and shark conservation strategies.

MATERIALS AND METHODS

Study period and location

This research was conducted from March 2023 to February 2024 in the Bali Strait, Indonesia. Data collection focused on shark catches landed at Brak Muncar Fish Landing Port (TPI) in Banyuwangi.

Data collection

Shark landing data were collected using a census method. Parameters recorded included species identification, total length (TL), and sex determination. Total length was measured horizontally from the mouth to the tip of the longest caudal fin lobe using a measuring tape. Sex was determined by examining the presence of a cloaca (female) or claspers (male). Male claspers were measured and classified into three maturity stages based on **Dharmadi and Fahmi (2006)**.

Materials and tools

Species identification relied on the reference guide "Identification Guide to Sharks, Rays, and Skates of the Southeast Asian Region" **(Ali *et al.*, 2017)**. Sea surface temperature (SST) data from March 2023 to February 2024 were sourced from the Marine Copernicus database. Temperature data were processed using QGIS software, with monthly visualizations generated via Inverse Distance Weighting (IDW) interpolation to estimate values at unsampled locations.

Data analysis

Quantitative descriptive analysis was employed to summarize field and satellite-derived data, presented as tables, histograms, and graphs. The relationship between SST and catch abundance was assessed using inferential statistics. A simple linear regression analysis was conducted after confirming data normality with the Liliefors test.

RESULTS AND DISCUSSION

1. Sea surface temperature conditions

Sea surface temperature (SST) in the Bali Strait from March 2023 to February 2024 exhibited monthly variability, ranging between 27.3 and 30.41°C (Fig. 1). Seasonal analysis revealed the lowest average temperature (27.3°C) during the east monsoon and the highest (30.3°C) during the west monsoon. This aligns with climatological processes described by **Hendiarti *et al.* (2005)**, where upwelling during the east monsoon brings cooler subsurface waters to the surface, while downwelling in the west monsoon drives warmer surface waters downward.

The observed SST range remained within the optimal thermal tolerance for marine biota. According to Indonesia's Ministry of Environment **(KLH, 2004)**, most marine organisms thrive at temperatures of 28–32°C, with permissible fluctuations below 2°C. These findings confirm that the Bali Strait's thermal regime remains conducive to supporting its aquatic ecosystems.

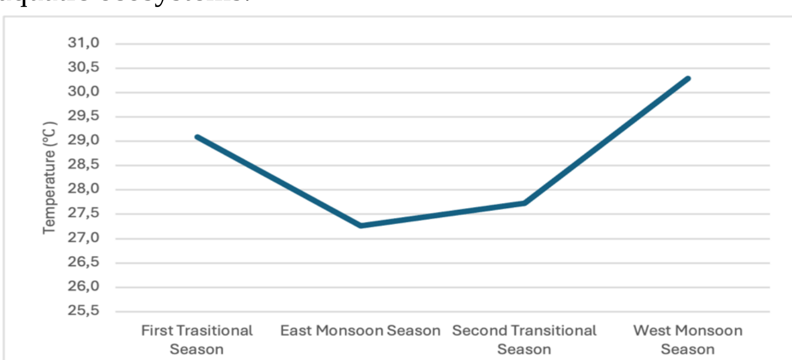

Fig. 1. Seasonal temperature distribution

2. Shark catch composition and seasonal patterns

Shark catches in the Bali Strait were obtained as bycatch from fisheries targeting mackerel, scad, and tuna. A total of 299 individuals across three species were recorded (Table 1), with *Atelomycterus marmoratus* (coral catshark; *n* = 140) and *Carcharhinus melanopterus* (blacktip reef shark; *n* = 131) dominating the catches, differing by only nine individuals. *Alopias pelagicus* (pelagic thresher) accounted for the remaining 28 individuals.

Table 1. Total shark catch

No.	Scientific Name	Local Name	Common Name	Count
1	*Alopias pelagicus*	Mungsing Lancur	Pelagic Thresher	28
2	*Carcharhinus melanopterus*	Kacangan	Blacktip Reef Shark	131
3	*Atelomycterus marmoratus*	Hiu Kucing / Mungsing tekek	Coral Catshark	140
Total				299

The high catch rates of *A. marmoratus* reflect its abundance in Indonesian waters, where it is frequently caught as bycatch due to its reef-associated habitat **(Oktaviyani *et al.*, 2019)**. Similarly, *C. melanopterus*, a common Indo-Pacific reef-dwelling species, thrives in the coral-rich ecosystems along Java's coast **(Luthfi *et al.*, 2016; Amir *et al.*, 2020)**.

All three species were captured year-round across four monsoon seasons (Transition I, east monsoon, Transition II, and west monsoon). *A. marmoratus* exhibited peak catches during Transition II and the west monsoon (September–April), coinciding with its breeding season, which increases mobility **(Oktaviyani *et al.*, 2019)**. *C. melanopterus* followed a similar seasonal trend, with elevated catches in Transition II and the west monsoon (Fig. 2). This aligns with studies in Australian waters, where reproductive activity and prey abundance (crustaceans and mollusks) peak during the rainy season (November–May) **(Mulyadi & Hernawati, 2022)**. In contrast, *A. pelagicus* catches peaked during the east monsoon and Transition II (June–October), corresponding to upwelling-driven surges in small pelagic fish, their primary prey **(Hendiarti *et al.*, 2005; Novianto *et al.*, 2020)**.

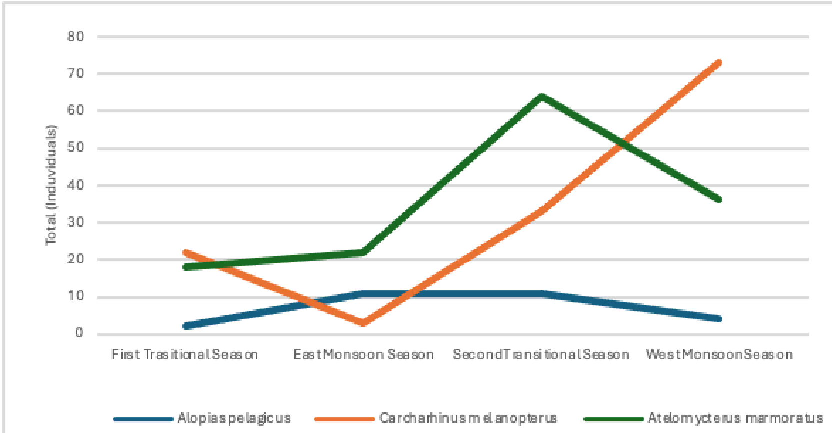

Fig. 2. Seasonal shark catch

3. Size frequency and sex ratio

a. *Alopias pelagicus*

The size distribution of *Alopias pelagicus* varied seasonally, with the majority of individuals (137.8–172.7cm total length) caught across all monsoon phases (Fig. 3). During Transition I, catches were split equally between the 102–136.8cm and 137.8–172.7cm size classes (1 individual each). In contrast, the east monsoon, Transition II and west monsoon seasons showed a consistent dominance of the 137.8–172.7cm size class. This suggests that most landed individuals were juveniles, as sexual maturity in this species is attained at 250–300cm total length **(Rigby *et al*., 2019)**.

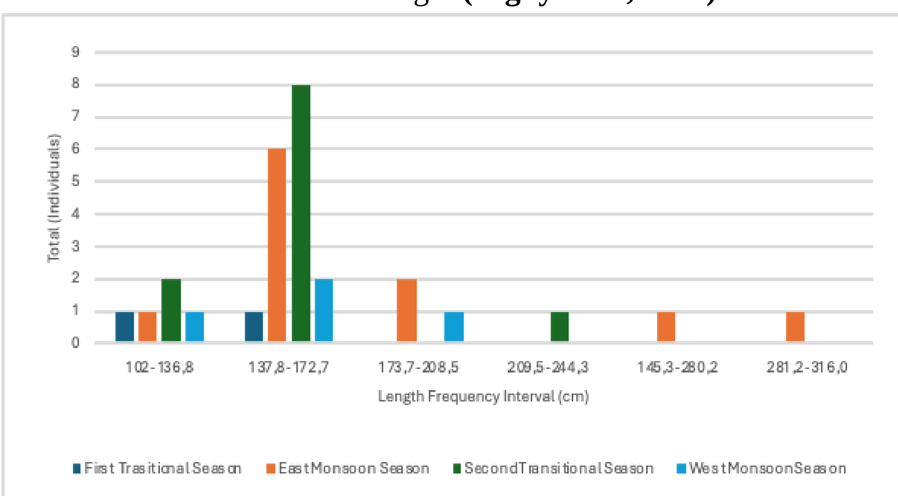

Fig. 3. *A. pelagicus* size frequency

Sex ratio analysis of the 28 captured individuals revealed a slight female bias (54%, n = 15) compared to males (46%, n = 13). Male clasper development, classified into three stages **(Dharmadi & Fahmi, 2006)**, showed near-equal distribution (Fig. 4): 39% (5 individuals) at Stage 1 (non-calcified), 38% (5 individuals) at Stage 2 (partially calcified), and 23% (3 individuals) at Stage 3 (fully calcified). A Chi-square test (χ^2 =

0.143, critical value = 3.841) confirmed no significant deviation from a 1:1 sex ratio ($P>$ 0.05), indicating balanced sex proportions in the catch.

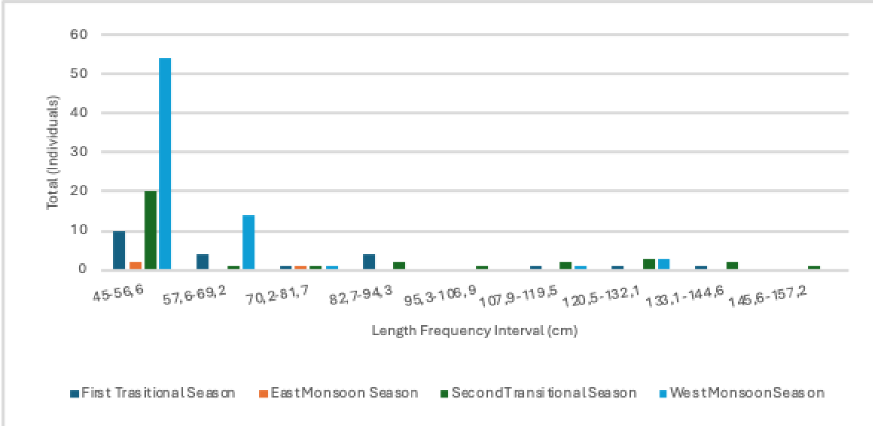

Fig. 4. *A. pelagicus* clasper stages

b. Carcharhinus melanopterus

The size distribution of *Carcharhinus melanopterus* across all seasons (Transition I, east monsoon, Transition II, and west monsoon) revealed a dominant size class of 45–56.6cm total length (TL) (Fig. 5). This indicates juvenile-dominated catches, as adults of this species, typically reach maturity at 90–134cm TL **(Simpfendorfer *et al.*, 2020)**.

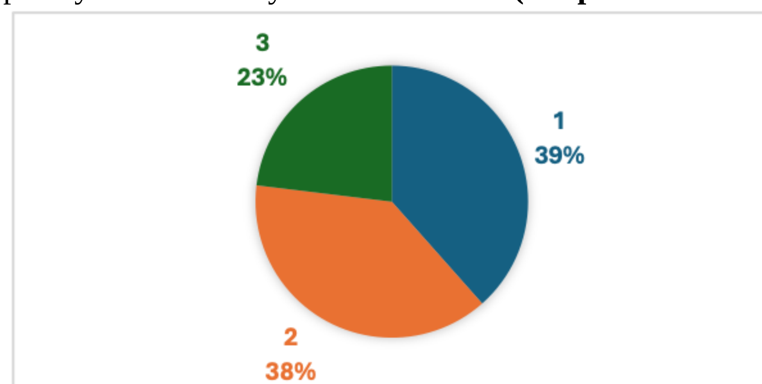

Fig. 5. *C. melanopterus* size frequency

Sex ratio analysis of the 131 captured individuals showed an equal proportion of males (50%, n = 65) and females (50%, n = 65). Male clasper maturity stages **(Dharmadi & Fahmi, 2006)** were predominantly in Stage 1 (non-calcified: 84%, n = 55) (Fig. 6), with fewer individuals in Stage 2 (partially calcified: 5%, n = 3) and Stage 3 (fully calcified: 11%, n = 7). This suggests that most males in the catch were immature and reproductively inactive. A Chi-square test (χ^2 = 0.008, critical value = 3.841) confirmed no significant deviation from a 1:1 sex ratio ($P>$ 0.05), supporting a balanced sex distribution in the landed catches.

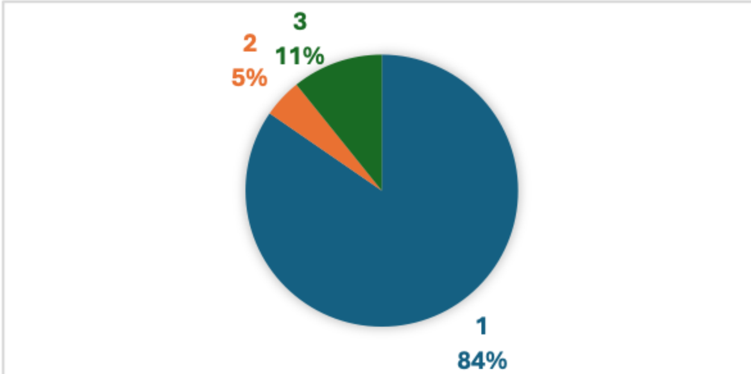

Fig. 6. *C. melanopterus* clasper stages

c. ***Atelomycterus marmoratus***

The size distribution of *Atelomycterus marmoratus* varied seasonally, with the dominant size classes shifting between monsoon phases. During Transition I and the west monsoon, most individuals in 45.4–48.6cm total length were captured, while catches in the east monsoon and Transition II seasons peaked in the 53.7–56.9cm TL range (Fig. 7). Overall, 45–56.6cm TL represented the most frequently caught size class across all seasons. According to **Ebert *et al*. (2013)**, adults of this species typically measure 47–62cm TL (males) and 49–57cm TL (females), suggesting that catches during Transition I and the west monsoon included both subadults and newly mature individuals.

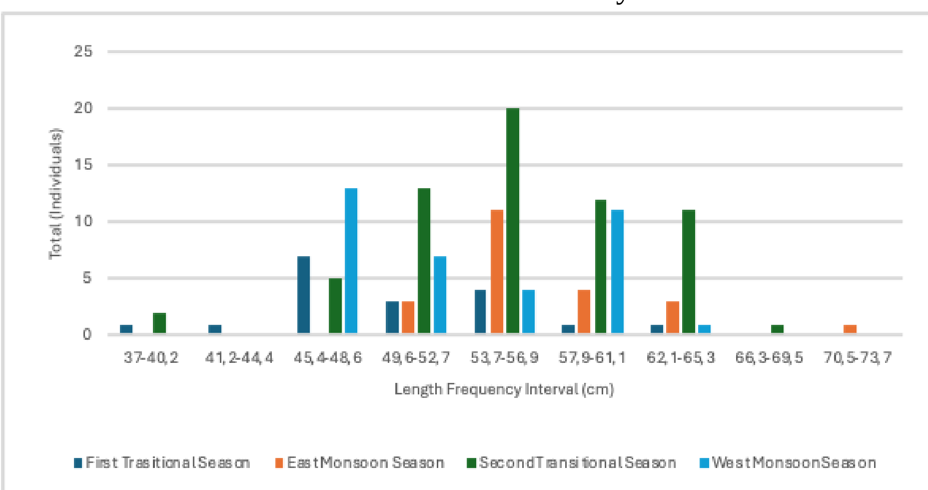

Fig. 7. *A. marmoratus* size frequency

Sex ratio analysis of the 140 captured specimens revealed a female-biased proportion (58%, n = 81) compared to males (42%, n = 59). Male clasper maturity stages **(Dharmadi & Fahmi, 2006)** were overwhelmingly dominated by Stage 3 (fully calcified: 93%, n = 55) (Fig. 8), with minimal representation of Stage 1 (non-calcified: 4%, n = 2) and Stage 2 (partially calcified: 4%, n = 2). This indicates that the majority of males in the catch were reproductively mature. A Chi-square test (χ^2 = 3.457, critical value = 3.841) revealed no significant deviation from a 1:1 sex ratio ($P > 0.05$), despite the numerical female domnance.

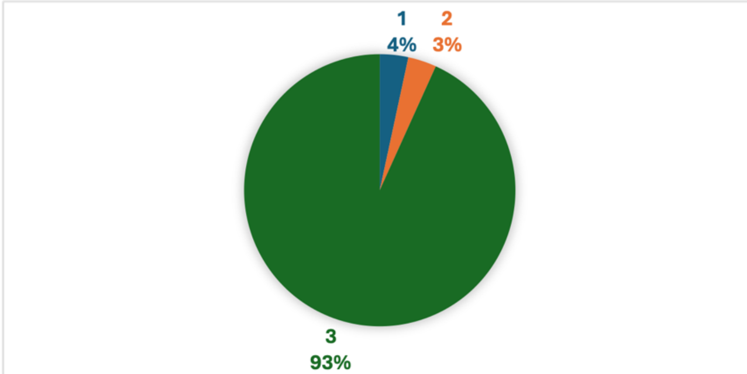

Fig. 8. *A. marmoratus* clasper stages

4. Relationship between temperature and shark catches

As ectothermic organisms, sharks rely on environmental temperatures to regulate their physiological processes **(Schlaff *et al.*, 2014)**. To assess the influence of sea surface temperature (SST) on catch abundance, a simple linear regression analysis was conducted using the correlation coefficient categories outlined in Table (2) **(Rachman *et al.*, 2024)**.

Table 2. Correlation coefficient interpretation

Coefficient range	Relationship strength
0.00-0.199	Very Weak
0.20-0.399	Weak
0.40-0.599	Moderate
0.60-0.799	Strong
0.80-1.000	Very Strong

a. *Alopias pelagicus*

Regression analysis revealed a moderate correlation (Multiple R = 0.496) between SST and catch abundance, with temperature explaining 24.6% of variability ($R^2 = 0.246$). This aligns with the species capacity for regional endothermy, which buffers physiological performance against temperature fluctuations **(Seitz, 2025)**. The remaining 75.4% of variability likely reflects prey availability, particularly during upwelling events.

b. *Carcharhinus melanopterus*

A strong positive correlation (Multiple $R = 0.650$) was observed, with SST accounting for 42.2% of catch variability ($R^2 = 0.422$). Juvenile growth and survival in this species are thermally mediated, with optimal performance at temperatures up to 31°C **(Bouyoucos *et al.*, 2020)**. The highest catches occurred during the west monsoon (peak SST: 30.3°C), consistent with their preference for warm, stable thermal regimes.

c. *Atelomycterus marmoratus*

Temperature showed negligible influence (Multiple R = 0.085; R^2 = 0.007), reflecting the species' sedentary behavior and strong site fidelity to coral reef habitats **(Oktaviyani *et al.*, 2019)**. As resident reef-dwellers, their distribution is less responsive to seasonal SST fluctuations compared to migratory species.

CONCLUSION

A study in the Bali Strait revealed the dominance of three shark species (*Alopias pelagicus*, *Carcharhinus melanopterus*, and *Atelomycterus marmoratus*) as bycatch in pelagic fisheries, with a total of 299 individuals captured. *A. marmoratus* (140 individuals) and *C. melanopterus* (131 individuals) dominated the catches, while the majority of captured individuals were juveniles, particularly *C. melanopterus* (45–56.6cm) and *A. pelagicus* (137.8–172.7cm), indicating exploitation pressure on immature populations. A balanced sex ratio (1:1) was observed across all species. Sea surface temperature (SST) significantly influenced *C. melanopterus* catches (R = 0.650), moderately affected *A. pelagicus* (R = 0.496), and had negligible impact on *A. marmoratus* (R = 0.085) due to its dependency on coral reef habitats. Study limitations include the one-year research period, which may not fully represent long-term trends, potential inaccuracies in satellite-derived temperature data, and the exclusion of other environmental factors such as salinity and anthropogenic pressures.

Policy recommendations emphasize the need for strict regulations to reduce by-catch, temporary no-catch zones in breeding areas, and harmonizing conservation policies with IUCN/CITES statuses. Management strategies should prioritize training fishers in selective fishing techniques, establishing community-based participatory monitoring systems, and integrating ecological data into science-based catch quotas. Future research should focus on long-term studies (5–10 years), genetic population analyses, and interdisciplinary approaches incorporating socio-economic aspects to strengthen shark conservation strategies and to ensure sustainable fisheries in Indonesia.

ACKNOWLEDGMENT

Thanks to all the committee members of the International Seminar of Indonesian Seas: Catalyst for Ocean Sustainability (ISCO) 2024, initiated by Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, who have facilitated the publication process of this manuscript until it was published in the Egyptian Journal of Aquatic Biology and Fisheries.

REFERENCES

Bouyoucos, I. A.; Morrison, P.R.; Weideli, O.C.; Jacquesson, E.; Planes, S.; Simpfendorfer, C.A.; Brauner, C.J. and Rummer, J.L. (2020). Thermal tolerance and hypoxia tolerance are associated in blacktip reef shark (Carcharhinus melanopterus) neonates. *Journal of Experimental Biology*, *223*(14). https://doi.org/10.1242/JEB.221937

Carr, L. A.; Stier, A. C.; Fietz, K.; Montero, I.; Gallagher, A.J. and Bruno, J.F. (2013). Illegal shark fishing in the Galápagos Marine Reserve. *Marine Policy*, *39*, 317–321. https://doi.org/10.1016/j.marpol.2012.12.005

Chin, A.; Simpfendorfer, C.; Tobin, A. and Heupel, M. (2013). Validated age, growth and reproductive biology of Carcharhinus melanopterus, a widely distributed and exploited reef shark. *Marine and Freshwater Research*, *64*(10), 965–975. https://doi.org/10.1071/MF13017

Dharmadi and Fahmi. (2006). Tingkat Kematangan Kelamin dan Frekuensi Panjang Pari Gitar (Rhinobatus sp. 1 & Rhinobatus sp. 2). *BAWAL Widya Riset Perikanan Tangkap*, *1*(1), 31–35. https://doi.org/10.15578/bawal.1.1.2006.31-35

Ebert, D. A.; Dando, M. and Fowler, S. (2013). *Shark of the World: A Complete Guide*. Wild Nature Press.

Eko W.M. and Ika Joesidawati, M. (2024). Aspek Biologi Ikan Hiu Appendiks II CITES Hasil Tangkapan Nelayan Muncar Banyuwangi. *Prosiding Seminar Nasional Penelitian Dan Pengabdian Masyarakat*, *9*(1), 1104–1111. http://prosiding.unirow.ac.id/index.php/SNasPPM

Hendiarti, N.; Suwarso, Aldrian, E.; Amri, K.; Andiastuti, R.; Sachoemar, S. and Wahyono, I.B. (2005). Seasonal Variation of Pelagic Fish Catch Around Java. *Oceanography*, *18*(4), 112–123. https://doi.org/10.5670/oceanog.2005.12

Heupel, M. and Simpfendorfer, C. (2011). Estuarine nursery areas provide a low-mortality environment for young bull sharks Carcharhinus leucas. *Marine Ecology Progress Series*, *433*, 237–244. https://doi.org/10.3354/meps09191

Huda, A. C. and Rini, O.P.K. (2021). Pemodelan Sebaran Kualitas Air di Pesisir Selat Bali Terhadap Ekosistem Perairan. *Jurnal Inovtek Polbeng*, *11*(2), 98–105.

Kamil, F.; Zurba, N. and Sihombing, A.C. (2023). Identification of the Diversity of Sharks and Rays Caught by Fishermen in Wpp 572, Rigaih Fish Landing Port, Aceh Jaya District. *Journal of Aceh Aquatic Science E*, *7*(2), 59–67.

KKP. (2011). *Kelautan dan Perikanan dalam Angka*. Pusat Data Statistik dan Informasi.

Motivarash, Y. B.; Kariya, P.C. and Dabhi, R. (2020). Importance of sharks in ocean ecosystem. *Journal of Entomology and Zoology Studies*. http://www.entomoljournal.com

Mulyadi, and Hernawati, R.T. (2022). Keanekaragaman dan Ketidaknormalan Morfologi Pada Komunitas Kopepoda (Krustasea) di Perairan Muara Angke dan Tanjung Pasir, Teluk Jakarta. *Berita Biologi*, *21*(3), 339–350. https://doi.org/10.14203/beritabiologi.v21i3.4367

Novianto, D.; Nugroho, A.F. and Zedta, R.R. (2020). *Composition and Abundance of Pelagic Shark Caught by Drift Gillnet in Cilacap Oceanic Fishing Port, Indonesia*. https://www.researchgate.net/publication/339400096

Oktaviyani, S.; Kurniawan, W. and Fahmi. (2019). Reproductive biology of coral catshark atelomycterus marmoratus (Anonymous [bennett], 1830) in Seribu Islands, Indonesia. *Biodiversitas*, *20*(8), 2166–2176. https://doi.org/10.13057/biodiv/d200810

Rachman, A.; Yochanan, E.; Samanlangi, A. I. and Purnomo, H. (2024). *Metode Penelitian Kuantitatif, Kualitatid dan R&D*. Saba Jaya Publisher.

Rigby, C.L.; Barreto, R.; Carlson, J.; Fernando, D.; Fordham, S.; Francis, M.P.; Herman, K.; Jabado, R.W.; Liu, K.M.; Marshall, A.; Pacoureau, N.; Romanov, E.; Sherley, R.B. and Winker, H. (2019). *Alopias pelagicus*. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T161597A68607857.en

Schlaff, A.M.; Heupel, M.R. and Simpfendorfer, C.A. (2014). Influence of environmental factors on shark and ray movement, behaviour and habitat use: a review. *Reviews in Fish Biology and Fisheries*, *24*(4), 1089–1103. https://doi.org/10.1007/s11160-014-9364-8

Seitz, J.C. (2025). *Pelagic Thresher: Alopias Pelagicus*. Florida Museum.

Simpfendorfer, C.; Yuneni, R.R.; Tanay, D.; Seyha, L.; Haque, A.B.; Fahmi; Bin Ali, A.; Bineesh, K.K.; Gautama, D. A.; Maung, A.; Sianipar, A.; Utzurrum, J. A.T. and Vo, V.Q. (2020). *Carcharhinus melanopterus*. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T39375A58303674.en

Sulaiman, P.S. and Triharyuni, S. (2021). Shark fisheries management as a sustainable development implementation in Indonesia fishery sector. *IOP Conference Series: Earth and Environmental Science*, *718*(1). https://doi.org/10.1088/1755-1315/718/1/012069

Wibowo, M.E. and Joesidawati, M.I. (2023). Variasi Ikan Hiu dan Pari Appendix II CITES Hasil Tangkapan Nelayan di Pelabuhan Perikanan Nusantara Brondong Lamongan. *Jurnal TECHNO-FISH*, *7*(1), 81–96. www.cites.org/eng/cop/index.php