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Comparative Analysis of Catch Efficiency and Seasonal Variations in Midwater Shark Longlining at Thengapattinam Fishing Harbour, Tamil Nadu

Archana Sethuraj[1]*, Neethiselvan Neethirajan[2], Padmavathy Pandurangan[3], Ravikumar Thangaraj[2], Uma Maheswari Thavasiyandi[2], Manikandan Boominathan[2], Durai Varatharajan[1], Mohammed Faizullah[1], Sundareswari Dhanabalan[2] and Ferolin Jessina George[1]

[1]*Dr. MGR Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Thalaianyeru*
[2]*Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Thoothukudi*
[3]*Tamil Nadu Dr. Jayalalithaa Fisheries University, Nagapattinam*

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MS conceived the research idea, designed the study, collected field data, conducted data analysis, and prepared the manuscript draft. She acted as the corresponding author and coordinated the research activities. NN provided critical guidance in designing the study framework, methodology, and data interpretation, while also reviewing and editing the manuscript. PP offered valuable inputs to enhance the manuscript's content. TR supported the conceptualization of the study, facilitated fieldwork, and provided feedback during manuscript preparation. TUM assisted in data collection, focusing on operational and catch-related param, and contributed to the initial analysis. NM for his invaluable guidance on the statistical analysis. VD, MMMF, MDS and MGFJ assisted in formatting, editing, and ensuring the manuscript adhered to publication standards.

Key words
Midwater longlining, Shark fisheries, Catch per unit effort (CPUE), Species composition, Seasonal variation, ANOVA analysis

ABSTRACT

This study evaluates the catch efficiency, vessel specifications, and seasonal variations of midwater longlining for sharks at Thengapattinam Fishing Harbour, (8.2341° N, 77.2991° E) Tamil Nadu. The research focuses on Type A (fiberglass, 18-20 m, 180-200 HP) and type B (steel, 20-22 m, 200-240 HP) vessels, analyzing gear configurations, species composition, and catch per unit effort (CPUE). Results indicate that type B vessels outperform type A vessels in total catch and efficiency. *Alopias* spp. (thresher shark) dominated by weight, contributing 29.61% (type A) and 31.04% (type B), while *Carcharhinus falciformis* (silky shark) was the most abundant by number, making up 29.58% (type A) and 29.19% (type B). Seasonal trends reveal that pre-monsoon catches were highest, with type A landing 1,886 sharks (63,986 kg) and type B capturing 2,022 sharks (73,847 kg). Monsoon yields were lowest, with type A and type B vessels recording 537 sharks (18,187 kg) and 542 sharks (22,555 kg), respectively. CPUE analysis confirmed significantly higher productivity during soaking hours, with type A vessels attaining 1.79 fish/hour (57.58 kg/hour) and type B vessels achieving 1.648 fish/hour (61.60 kg/hour). ANOVA results showed significant differences in CPUE across months ($F = 6.78$, $p < 0.001$), species ($F = 8.13$, $p < 0.001$), and seasons ($F = 14.12$, $p < 0.001$). The study highlights the operational advantages of type B vessels while emphasizing the importance of sustainable fishing practices. Selective fishing techniques and seasonal regulations could enhance conservation efforts while maintaining economic viability for fishers.

INTRODUCTION

Sharks play a crucial role in marine ecosystems as apex predators, regulating species populations and maintaining biodiversity by preying on weaker individuals (Karnad *et al*., 2020; Mohanraj *et al*., 2024). Their presence supports ocean health and ecosystem stability, but growing global demand for shark-derived products, particularly fins for East Asian cuisine and meat in parts of Asia and Europe, has led to significant overfishing pressures (Nagle, 2019). The high commercial value of these products has resulted in unsustainable fishing practices, including targeted longlining and incidental bycatch in multi-species fisheries, raising ecological and conservation concerns (Kizhakudan *et al*., 2019; Sivadas *et al*., 2019). Sharks have slow reproductive rates, making their populations highly vulnerable to overexploitation. Several species are now classified as threatened or endangered, necessitating

* Corresponding author: fishco.archana@gmail.com
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urgent conservation measures (IUCN Shark Specialist Group, 2021). In Tamil Nadu, India, the extensive Bay of Bengal coastline supports a rich marine biodiversity, including commercially valuable sharks such as *Alopias* spp. and *Carcharhinus falciformis,* which are primarily caught using midwater longlining (Menon *et al*., 2023; Sivadas *et al*., 2019). Shark fisheries provide significant economic benefits to Tamil Nadu's coastal communities, but there is a pressing need to balance commercial exploitation with sustainability efforts (Kizhakudan *et al*., 2019; Ravikumar *et al*., 2024). Midwater longlining systems (MLS) have become a preferred fishing method for targeting large pelagic sharks while reducing bycatch compared to gillnets and bottom trawling (Raut *et al*., 2023). By suspending baited hooks at specific depths, MLS enhances selectivity and minimizes the unintended capture of non-target species, making it a more sustainable alternative to other fishing methods (Sasipriyan *et al*., 2024). However, careful management and regulatory measures are necessary to prevent overfishing and ensure the long-term viability of shark populations in Tamil Nadu (FAO, 2023). This study aims to contribute to sustainable shark fisheries by analyzing MLS gear design, catch composition, and catch per unit effort (CPUE). Additionally, the research seeks to provide insights into best practices for optimizing shark fisheries to balance economic profitability with ecological conservation (FAO, 2023; Ravikumar *et al*., 2024).

MATERIALS AND METHODS

Study area and sampling frequency

This study was conducted at Thengapattinam Fishing Harbour (8.2341° N, 77.2991° E) on the southeast coast of Tamil Nadu, with bi-monthly sampling. Data were collected from 15% of MLS gear-craft operations using Type A and Type B vessels.

Technical specifications of deep sea fishing vessels

Technical details of deep-sea fishing vessels targeting sharks with midwater longlines were recorded, including overall length (OAL), construction material, operational range, engine power, and endurance capacity (FAO, 2014).

MLS gear design and operational details

To analyze the technical and operational specifications of midwater longline systems (MLS) targeting shark fisheries, detailed data on gear configurations and operational details were collected from Thengapattinam fishing harbour, Kanyakumari district , Southeast coast of Tamil Nadu,. The study aimed to gather comprehensive information on the design, setup, and specific configurations of MLS gear used in fishing operations, including details on line dimensions, hooks, floats, sinkers, and bait used (FAO, 2001).

Catch data

Catch data, recorded by species count and weight according to FAO standards. To analyze the month-wise species composition and seasonal catch, the percentage of each species within the total catch was calculated separately for each month. For the seasonal analysis, the monthly data were grouped into broader seasonal categories (such as monsoon, post monsoon and pre monsoon).

Catch per unit effort (CPUE)

CPUE for soaking time, presented in terms of number of fish and weight of fish is calculated using the following formula.

$$\text{CPUE}\left(\frac{\text{Fish/kg}}{\text{Hour}}\right) = \frac{\text{Total Fish Caught(Number/Kg)}}{\text{Total Soaking time (Hours)}}$$

Statistical analysis

The ANOVA F-value to evaluate the effects of month, species, season on CPUE is calculated using the following formula:

$$F = \frac{\text{Mean Square between groups}}{\text{Mean square wihtin groups}}$$

RESULTS

Technical specification of deep-sea fishing vessels

The technical specifications of the two deep-sea fishing vessel types used in midwater longlining for sharks (MLS) at Thengapattinam Fishing Harbour highlight their distinct operational capabilities. Type A vessels, built from fiberglass-reinforced plastic (FRP), measure 18–20 m in length and are powered by 180–200 HP engines. These vessels are fuel-efficient and cost-effective, making them ideal for medium-range operations within 100–150 nautical miles. However, their limited endurance restricts extended offshore fishing. In contrast, type B vessels, constructed from steel and ranging from 20–22 m in length with 200–240 HP engines, are designed for long-distance fishing. With the capacity to operate up to 200 nautical miles offshore, they are better suited for targeting larger pelagic species in deeper waters.

Gear design and configurations of midwater longlining for sharks (MLS)

The MLS gear setup for type A and type B vessels is designed for shark fishing, with notable differences in specifications. Type A vessels have a 31.5 km mainline, while type B vessels extend to 36.0 km, both with a diameter of 180–200 mm. Both vessel types use polyamide (PA) monofilament branch lines measuring 4.0 m, spaced 45 m apart. Type A vessels carry 28 baskets with 700 hooks, while type B vessels hold 32 baskets with 800 hooks, all using hook size 0. Floats are spaced 280 m apart, with type A using 26 marker floats and type B using 30, both positioned at 945-m intervals. Each vessel type has two master floats, spaced 22.5 km apart for type A and 27.0 km for type B. The sinker configurations differ slightly. Type A vessels use eight sinkers weighing two kilog each, placed every 63rd branch line, while type B vessels use nine sinkers of the same weight at the same interval. Both vessel types have two additional master float sinkers weighing four kg and a bridle sinker weighing one kg. Flag poles are placed every 2.835 km, with eight on type A and nine on type B, along with two fleet-end flag poles and five AIS transponders. Trevally weighing 300–350 g is used as bait, and the marker float system consists of two 35-L floats per unit (Fig. 1).

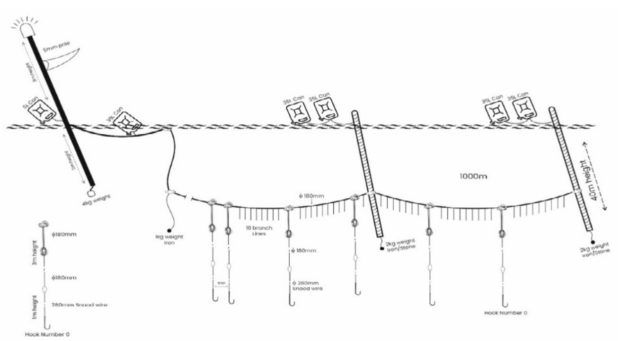

Fig. 1. Schematic representation of a midwater longline (MLS) for pelagic shark. The diagram illustrates a the 1000-meter mainline is suspended 40 m deep using 1–4 kg weights and 38-liter buoyant cans. Branch lines with 280 mm snood wires and Hook Number 0 are spaced along the mainline, with hooks set 1–3 m below. Each branch line holds 10 hooks, maximizing catch efficiency.

Species composition and catch analysis of type A vessel and type B vessel

The species composition analysis shows that *Alopias* spp. (thresher shark) dominates the catch by weight, contributing 29.61% in type A and 31.04% in type B vessels, with a slightly lower presence in numbers at 25.17% and 25.14%, respectively. *Carcharhinus falciformis* (silky shark) ranks second by weight, comprising 17.98% in type A and 16.36% in type B, while being the most abundant species in numbers at 29.58% and 29.19%. *Galeocerdo cuvier* (tiger shark) contributes 14.72% (type A) and 14.00% (type B) by weight, but its numerical presence is lower, indicating larger individual sizes. Similarly, *Sphyrna lewini* (scalloped hammerhead) accounts for 9.32% (type A) and 9.08% (type B) by weight, with a lower proportion in numbers at 2.97% and 2.91%, suggesting larger specimens. *Carcharhinus macloti* (hard nose shark) contributes 9.22% (type A) and 8.48% (type B) by weight, with lower numerical representation in both vessels. *Carcharhinus limbatus* (common blacktip shark) is more prevalent in type B vessels by weight (9.04%) than type A (7.46%), while its numerical distribution remains similar. Minor species include *Carcharhinus dussumieri* (white cheek shark), *Carcharhinus melanopterus* (black tip reef shark), *Isurus oxyrinchus* (shortfin mako shark), *Isurus paucus* (longfin mako shark), and *Lamna nasus* (porbeagle), each contributing less than 5% in weight and number, with slight variations between vessel types (Fig. 2).

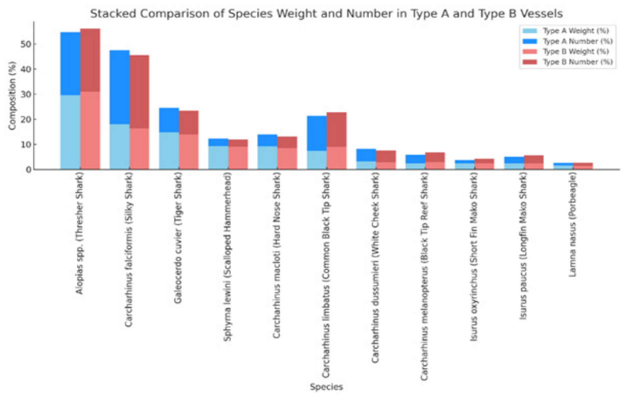

Fig. 2. Species-specific percentage composition of catch by number and weight for type A and type B vessels. This figure compares catch composition between type A and type B vessels in midwater shark longlining, highlighting differences in species distribution, catch efficiency, and targeting patterns.

Table I. ANOVA for significant param affecting fishing gear efficiency in MLS .

Gear	Significant param	F-value	F-Table value	Sig.
MLS	Month-wise	6.78	4.84	0.000
	Species-wise	8.13	5.12	0.000
	Season-wise	14.12	10.13	0.000

Catch per unit effort (CPUE)

CPUE, which measures the number of fish caught per hour, soaking hours show much higher productivity than running hours. For instance, type A vessels catch an average of 1.79 fish per hour and 57.58 kg per hour during soaking while, type B vessels attain a CPUE of 1.648 fish per hour and 61.60 kg per hour during soaking (Fig. 4).

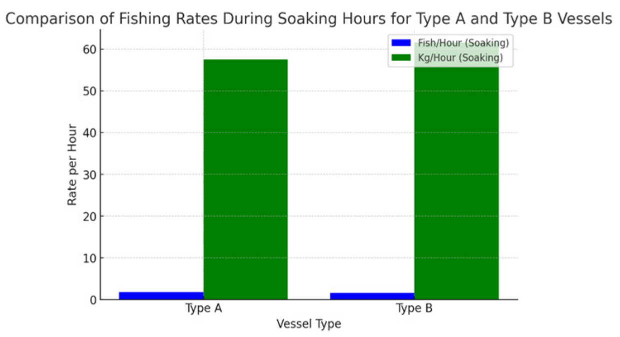

Fig. 3. Comparative fishing efficiency of type A and type B vessels based on catch rates (fish count and weight) during soaking hours.

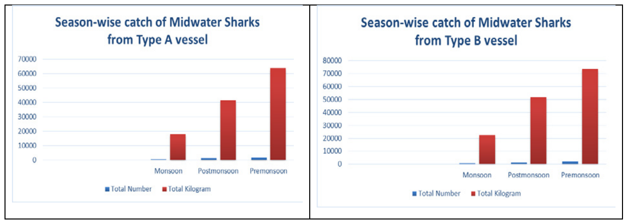

Fig. 4. The graphs depict seasonal catch variations for type A and type B vessels, showing total shark numbers (blue bars) and weight (red bars) across monsoon, post-monsoon, and pre-monsoon seasons. The monsoon season records the lowest catches due to harsh weather limiting fishing activity. Post-monsoon sees an increase, while pre-monsoon yields the highest catch, reflecting optimal fishing conditions and shark abundance.

Seasonal variation in fish catch for type A and type B vessels

The season-wise analysis of shark catches by type A and type B vessels, highlighting the total number and weight (kg) of various shark species across the monsoon (June–September), post-monsoon (October–December), and pre-monsoon (January–May) seasons. Both vessel types exhibit the highest catch during the pre-monsoon season, with type A vessels recording 1,886 sharks (63,986 kg) and type B vessels achieving 2,022 sharks (73,847 kg). Conversely, the monsoon season yields the lowest productivity, with type A and type B vessels catching 537 sharks (18,187 kg) and 542 sharks (22,555 kg), respectively. Species-specific trends reveal that silky sharks (*Carcharhinus falciformis*) dominate catches in both vessels, particularly during the pre-monsoon season, while tiger sharks (*Galeocerdo cuvier*) and thresher sharks (*Alopias*) also contribute significantly. Notably, type B vessels consistently outperform type A vessels in total catch across all seasons, reflecting their superior capacity and efficiency for offshore fishing (Fig. 3).

ANOVA of significant param in MLS

ANOVA analysis for the significant param in MLS gear and highlights the statistical importance of each of the evaluated factors. For the Month parameter, the F-value is 6.78, higher than the F-table valued at 4.84, while the significance shows .000, hence showing a meaningful variation across months. In the same manner, Species can be seen to have an F-value of 8.13, higher than the F-table value of 5.12, also at a significance level of .000, thus showing significant differences among species. The Season then depicted a significant seasonal effect having an F-value of 14.12, which is higher than that on the F-table of 10.13 at a significance level of 0.000 (Table I).

DISCUSSION

Technical specifications of deep-sea fishing vessels

Type A and type B vessels exhibit distinct characteristics influencing their range, efficiency, and suitability for deep-sea fishing. Type A vessels (fiberglass, 180-200 HP) are designed for medium-range operations (100-150 nautical miles). Their lighter construction reduces drag, improving efficiency for shorter trips but limiting endurance for extended offshore fishing (Subadra *et al*., 2020; Szelangiewicz *et al*., 2021). In contrast, type B vessels (steel, 200-240 HP) are built for long-distance fishing (up to 200 nautical miles). Their robust steel construction enhances endurance, making them suitable for deep-sea operations, though with higher operational costs (Sala *et al*., 2011; Basurko *et al*., 2013). These findings emphasize the trade-off between vessel efficiency, operational range, and capacity in deep-sea shark fisheries (Parker and Tyedmers, 2014).

Gear design and configurations of mid water longline for sharks (MLS)

The gear configurations of type A and type B vessels highlight significant differences in fishing capacity and efficiency. Type A vessels, with a mainline of 31.5 km and 700 hooks, are configured for smaller-scale catches, while type B vessels, featuring a longer mainline of 36.0 km and 800 hooks, have a greater catch capacity. This relationship between line length, hook count, and catch volume is consistent with studies indicating that increased line and hook size enhances overall catch rates (Gilman *et al*., 2018). Both vessel types use PA monofilament branch lines and a uniform marker float system, which is beneficial for targeting specific species while reducing bycatch (Beverly *et al*., 2009). Standardized hooks and floats across both vessel types support sustainable fishing practices by reducing unintended capture of non-target species, a strategy shown to be effective in minimizing bycatch in pelagic fisheries (Jiménez *et al*., 2018). However, the additional hooks and increased basket capacity of type B vessels necessitate greater fuel for deployment and retrieval, leading to higher operational costs and environmental impacts due to elevated fuel use and emissions (Parker and Tyedmers, 2014).

Species composition and catch analysis by vessel types

The analysis of species composition shows that *Alopias* spp. (thresher shark) is the most common catch for both types of vessels, followed by *Carcharhinus falciformis* (silky shark). This trend aligns with global patterns observed in pelagic shark fisheries (Saldana-Ruiz *et al*., 2017). Furthermore, larger species like *Galeocerdo cuvier* (tiger shark) and *Sphyrna lewini* (scalloped hammerhead) contribute significantly to the total catch weight, even though they are caught in smaller numbers. This indicates a selective focus on high-value species (Cortés *et al*., 2010). The regular capture of smaller species such as *Carcharhinus macloti* and *Carcharhinus limbatus* highlights the diversity present in the MLS fishery, which, like other shark fisheries, captures a range of species due to variations in fishing depths and gear types (Peiris *et al*., 2021).

CPUE

The CPUE analysis highlights that both type A and type B vessels achieve higher productivity during soaking hours, emphasizing the efficiency of actively fishing time (Mullowney and Dawe, 2009). Research suggests that maximizing soaking time when fishing gear is deployed boosts yields (Basurko *et al*., 2013). Type B vessels, which often target larger species or operate with longer intervals between fishing grounds, demonstrate slightly higher CPUE in terms of weight per hour during soaking. This aligns with studies indicating that larger hook and line capacities yield greater catch volumes (Foster *et al*., 2017) and that vessel size and gear configuration influence efficiency (Mahevas et al., 2004).

Seasonal variation in fish catch

The seasonal variation in fish catch for type A and type B vessels highlights the operational efficiency and species-specific productivity of these vessels across different seasons. Both vessel types recorded peak catches during the pre-monsoon season, with type A vessels landing 1,886 sharks (63,986 kg) and type B vessels achieving a higher catch of 2,022 sharks (73,847 kg), reflecting the favorable sea conditions and abundance of fish during this period (Sakshaug, 1997). In contrast, the monsoon season showed the lowest productivity, with harsh weather conditions limiting fishing operations and resulting in minimal catches for type A (537 sharks, 18,187 kg) and type B vessels (542 sharks, 22,555 kg), as noted in studies on monsoon impacts on fisheries (Thomas *et al*., 2016). The post-monsoon season displayed moderate recovery in catches due to improving weather conditions. Species-specific trends indicate that silky sharks (*Carcharhinus falciformis*) dominated the catch for both vessel types, particularly in the pre-monsoon season, consistent with their known seasonal abundance (Sreekanth and Lekshmi, 2016). Tiger sharks (*Galeocerdo cuvier*) and thresher sharks (*Alopias*) also contributed significantly to the total catch. Notably, type B vessels consistently outperformed type A vessels in total catch across all seasons due to their higher capacity and efficiency for offshore fishing, albeit at a higher environmental cost (Szelangiewicz *et al*., 2021).

CONCLUSION

This study provides a comprehensive analysis of the catch efficiency, technical specifications, and seasonal variations of deep-sea fishing vessels engaged in midwater longlining for sharks at Thengapattinam Fishing Harbour, Tamil Nadu. The findings highlight the significant differences between type A and type B vessels in terms of operational range and catch composition. Type B vessels, with their larger size, higher endurance, and increased hook capacity, demonstrated greater overall catch efficiency compared to type A vessels. The gear configurations used in MLS operations were found to be effective in targeting pelagic sharks while reducing bycatch, reinforcing the importance of selective fishing techniques. Species composition analysis revealed that *Alopias* spp. (thresher shark) and *Carcharhinus falciformis* (silky shark) dominated the catch, with significant seasonal variations influencing catch rates. The highest catches were recorded in the pre-monsoon season, while the monsoon season yielded the lowest productivity due to unfavorable sea conditions. The CPUE analysis confirmed high productivity during soaking hours, emphasizing the efficiency of midwater longlining in maximizing catch rates. Statistical analysis using ANOVA further validated the significant impact of seasonality, species type, and operational factors on CPUE.

DECLARATIONS

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IRB approval

Ethical approval for the study was obtained from the Institutional Research Committee, Tamil Nadu Dr. J. Jayalalithaa Fisheries University.

Ethics statement

All procedures followed were in accordance with the ethical standards of the institution and the ICAR research guidelines for fisheries. No animal was harmed during the study.

Statement of conflict of interest

The authors declare no conflict of interest related to the study. The research was conducted independently, and there are no financial, commercial, or personal relationships that could influence or bias the work presented. All findings and recommendations are based solely on the data and analysis performed, aiming to contribute to sustainable fishing practices and environmental conservation.

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