

TUNA HANDLINES IN SABAH: TECHNICAL ATTRIBUTES, OPERATIONAL DYNAMICS, AND GROSS PROFIT MARGINS

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ABSTRACT. *Tuna fisheries in Malaysia employ a variety of gears, with handlines representing the most widely licensed and practiced method, particularly in Sabah and Labuan. Despite their importance, detailed assessments of artisanal tuna handline fisheries remain limited. This study evaluates vessel specifications, gear attributes, operational dynamics, and economic performance of handline tuna fisheries across three localities: Kota Kinabalu, Semporna, and W.P. Labuan. Data were collected through structured interviews with 30 respondents, supplemented with field documentation of fishing gear. Results indicate that vessel capacity and engine horsepower vary considerably, with Kota Kinabalu operators employing larger, higher-horsepower vessels, enabling operations in distant fishing grounds compared to Semporna and Labuan. Handline structures were standardized across sites, comprising mainlines, swivels, sinkers, and C- or J-shaped hooks, with C-shaped hooks associated with higher catch rates and profitability. Fishing operations were closely linked to Fish Aggregating Devices (FADs), with trip frequencies ranging from three to four per month. Economic analysis revealed substantial variation, with gross profits per trip ranging from RM 2,171 in Semporna to RM 15,450 in Kota Kinabalu. Findings provide critical insights into the technical and economic dimensions of artisanal tuna handline fisheries, offering evidence to inform sustainable management and policy development.*

INTRODUCTION

In Malaysia, several types of fishing gear are used to catch tuna. The equipment and methods of operation vary depending on the fishing location, whether in shallow waters or the deep sea. Tuna is normally caught using gear such as longlines and handlines to target oceanic tuna species like Skipjack Tuna (*Katsuwonus pelamis*), Yellowfin Tuna (*Thunnus albacares*), Bigeye Tuna (*Thunnus obesus*), and Albacore (*Thunnus alalunga*). In addition to longlines and handlines, purse seines are also used to catch neritic tuna species such as Longtail Tuna (*Thunnus tonggol*), Kawakawa (*Euthynnus affinis*), Frigate Tuna (*Auxis thazard*), and Bullet Tuna (*Auxis rochei*). In the global fisheries sector, the use of longlines and handlines represents two types of fishing gear with distinct modes of operation. For example, in industrial fisheries, large vessels are used to catch tuna in deep-sea waters, equipped with advanced detection systems and mechanical navigation, requiring high capital investment. In addition, there are

also small-scale and artisanal fisheries that operate with smaller boats and shorter operational periods compared to large-scale industrial fisheries. Handline fishing, on the other hand, is practiced by traditional fishermen in the South China Sea and Sulu Sea islands in Sabah.

According to the Malaysian Fisheries Statistics 2023, handlines represent the largest number of licensed fishing gear in Malaysia, totaling 6,525 units. The total landing of oceanic tuna amounted to 3,390 tonnes, with the majority 2,766 tonnes or 82% of the landings caught using handlines. Previous studies have shown that the use of handline gear by the Malaysian Fisheries Training Institute in 1988 successfully captured oceanic tuna in areas around Fish Aggregating Devices (FADs) near Layang-Layang Island in Sabah (Johari, 1989). There are studies carried out in different localities in the reporting on the uses of tuna handlines (Danial *et al.* 2023, Kurniawan *et al.* 2020, Hargiyatno *et al.* 2021, Nguyen *et al.* 2022 and Ajik & Tahluddin, 2021). Despite the growing importance of artisanal tuna fisheries in Malaysia, particularly in Sabah, comprehensive data on gear specifications, fishing operations, and economic performance remain limited. This study addresses this knowledge gap by evaluating the technical attributes, operational dynamics, and gross profit margins of artisanal tuna fishermen in Sabah. The findings contribute to a deeper understanding of small-scale tuna fisheries and offer valuable insights to inform evidence-based fisheries management and policy formulation in the region.

MATERIALS AND METHODS

This study was conducted in Sabah (Kota Kinabalu and Semporna) and W.P Labuan which are located in the South China Sea Coast and the main economic activity in these three localities is fishery. The study was conducted from January to December 2024. A complete questionnaire form was prepared. To collect data on tuna handline, a total of 30 respondents were interviewed. The data collected included information on boat owners and crews, gear specifications, operational details and economic affairs. All the data were analysed using Microsoft Excel and the gear specifications used by the respondents were also documented. The estimated percentage of operating cost margins was calculated using this formula, Operating Cost (Ringgit Malaysia, RM)/ Catch Value (RM) x 100. The estimated Gross Profit per trip was calculated using this formula, Catch Value (RM) – Total Operating Cost (RM). Statistical analyses were performed using PAST (PAleontological STatistics software), an open-source platform for comparing group means and medians. In this study, a Kruskal-Wallis test was applied to assess differences among groups since the data that did not meet normality assumptions.

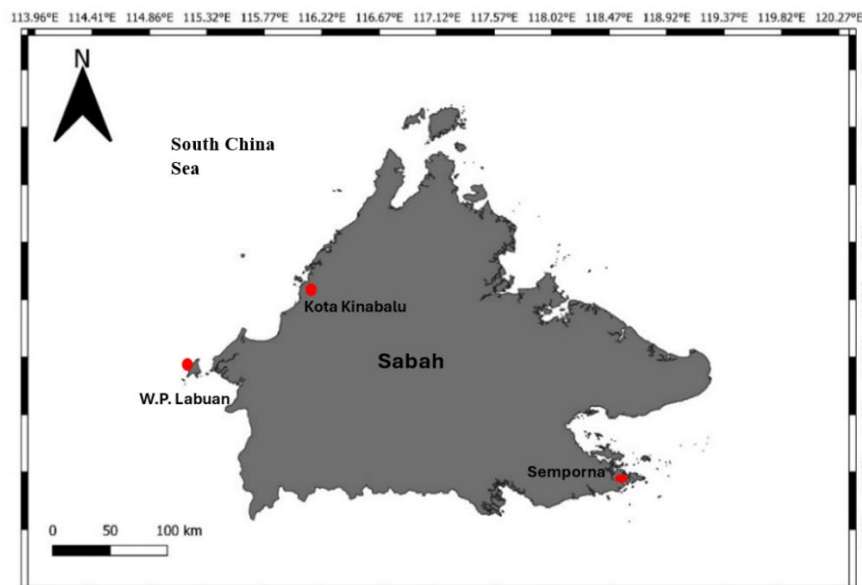


Figure 1. Study site involved three localities viz. Kota Kinabalu, W.P Labuan and Semporna (The map was generated using QGIS Desktop 3.34.1, an open-source geographic information system (<https://download.qgis.org>))

RESULTS AND DISCUSSION

General Specification of Vessels


The Gross Registered Tonnage (GRT) capacity of vessels in Semporna shows variation, ranging from 1.17 to 4.77. However, GRT data were not recorded for vessels in Kota Kinabalu and the W.P Labuan, limiting the comparative analysis of vessel capacity. In terms of engine horsepower (HP), vessels in Kota Kinabalu use more powerful engines, with 350 HP, compared to those in Semporna (40 HP and 15 HP) and Labuan (40 HP). Two out of four vessels in Semporna and also in Labuan use twin engines on a single vessel. The use of higher horsepower Cummins engines suggests that tuna handline vessels in Kota Kinabalu are capable of operating in more distant fishing grounds compared to the other two locations.

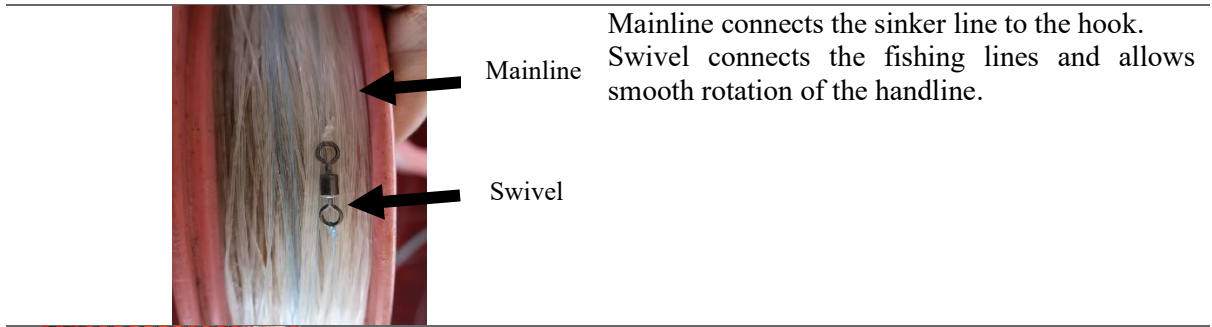
Tuna Handlines

In general, a handline consists of four main components: the mainline, swivels, sinkers, and hooks, as shown in Table 1. The fishing line commonly used is monofilament due to its strength and water resistance. To connect the lines and allow smooth rotation, standard barrel swivels are used in the tuna handline setup. In addition, sinkers such as lead and stone weights are used to bring the bait down to the desired depth. There are two types of hooks used by tuna handline fishermen: C-shaped hooks and J-shaped hooks. The main difference between these two hook types lies in the bait used. J-hooks are typically used with artificial lures such as coin-shaped metal jigs, plastic fish replicas, and polymer materials like feathers. On the other hand, C-shaped hooks are used with natural bait such as squid, squid ink, and fish meat slices to attract tuna. Fresh squid, caught using squid jigging gear, is commonly used as bait. According to Nghiep & Khanh (2025), the previous study revealed that C-shaped hooks yield 18% higher landing volume, attributed to the capture of larger-sized individuals. This size advantage translates into significantly greater economic returns for fishers, highlighting the potential of C-shaped hooks to enhance the profitability of handline tuna fisheries.

The adoption of C-shaped hooks has been shown to significantly enhance catch rates of target species such as Yellowfin Tuna (*T. albacares*) and Bigeye Tuna (*T. obesus*) compared with traditional J-shaped hooks, particularly in pelagic longline fisheries (Reinhardt *et al.*, 2017; Kerstetter & Graves, 2006; Sales *et al.*, 2010). Beyond improvements in capture efficiency, C-shaped hook design also confers important ecological benefits. Empirical studies demonstrate that C-shaped hooks substantially reduce the incidence of deep hooking, thereby lowering post-release mortality and mitigating bycatch of vulnerable non-target taxa, including sea turtles as well as sharks and rays (Sales *et al.*, 2010; Santos, 2023). Collectively, this body of evidence underscores the dual advantage of C-hook implementation: enhancing fishery yields while aligning with ecosystem-based management principles through bycatch reduction. These findings reinforce the role of C-shaped hooks as a practical, evidence-driven intervention to improve both the sustainability and economic viability of industrial pelagic longline fisheries. The technical attributes and configurations of tuna handlines in Semporna, W.P Labuan and Kota Kinabalu are illustrated in Figures 2–4. These schematics highlight the gear characteristics specific to each surveyed locality.

Table 1: General handline components and its functions

Components Image	Components and its function
	Handline/ <i>Koyan</i> – used for storing fishing lines.



Mainline connects the sinker line to the hook.
Swivel connects the fishing lines and allows smooth rotation of the handline.



Lead/stone sinker - lowers the bait to the appropriate depth.



Hook – attaches to the tuna's mouth when the bait is taken.
Coin-shaped bait – used with J-shaped hooks; the shiny, reflective surface attracts the attention of tuna.



Artificial fish bait – used with J-shaped hooks to attract tuna.



Feather bait – used with J-shaped hooks to attract tuna.



Squid ink bait – tied together with a sinker and dropped along with bait to simulate live squid in the water

Types of Gear: Tuna Handline

Location : Semporna

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

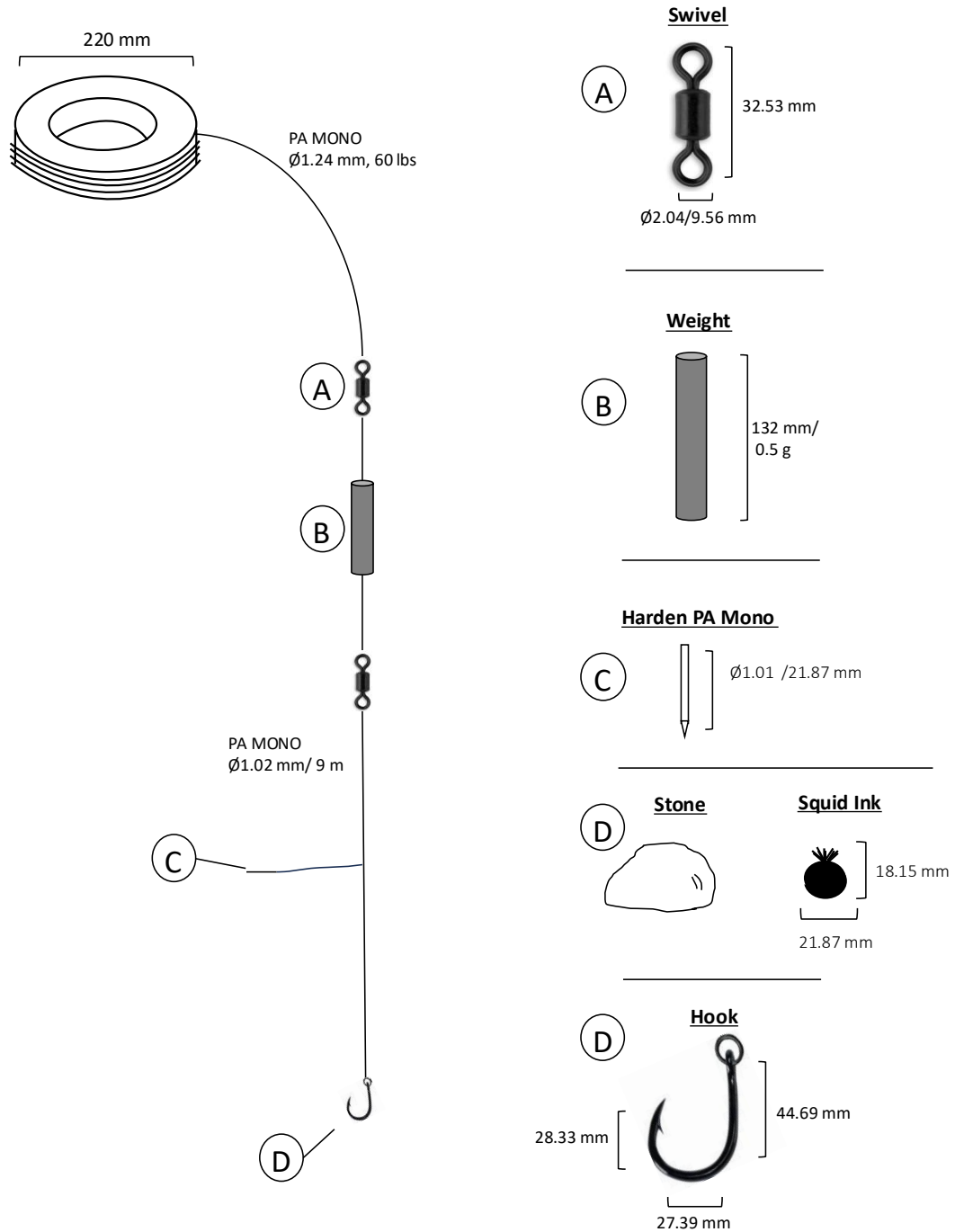


Figure 2a.: Technical attributes of tuna handline in Semporna

Types of Gear: Tuna Handline

Location : Semporna

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

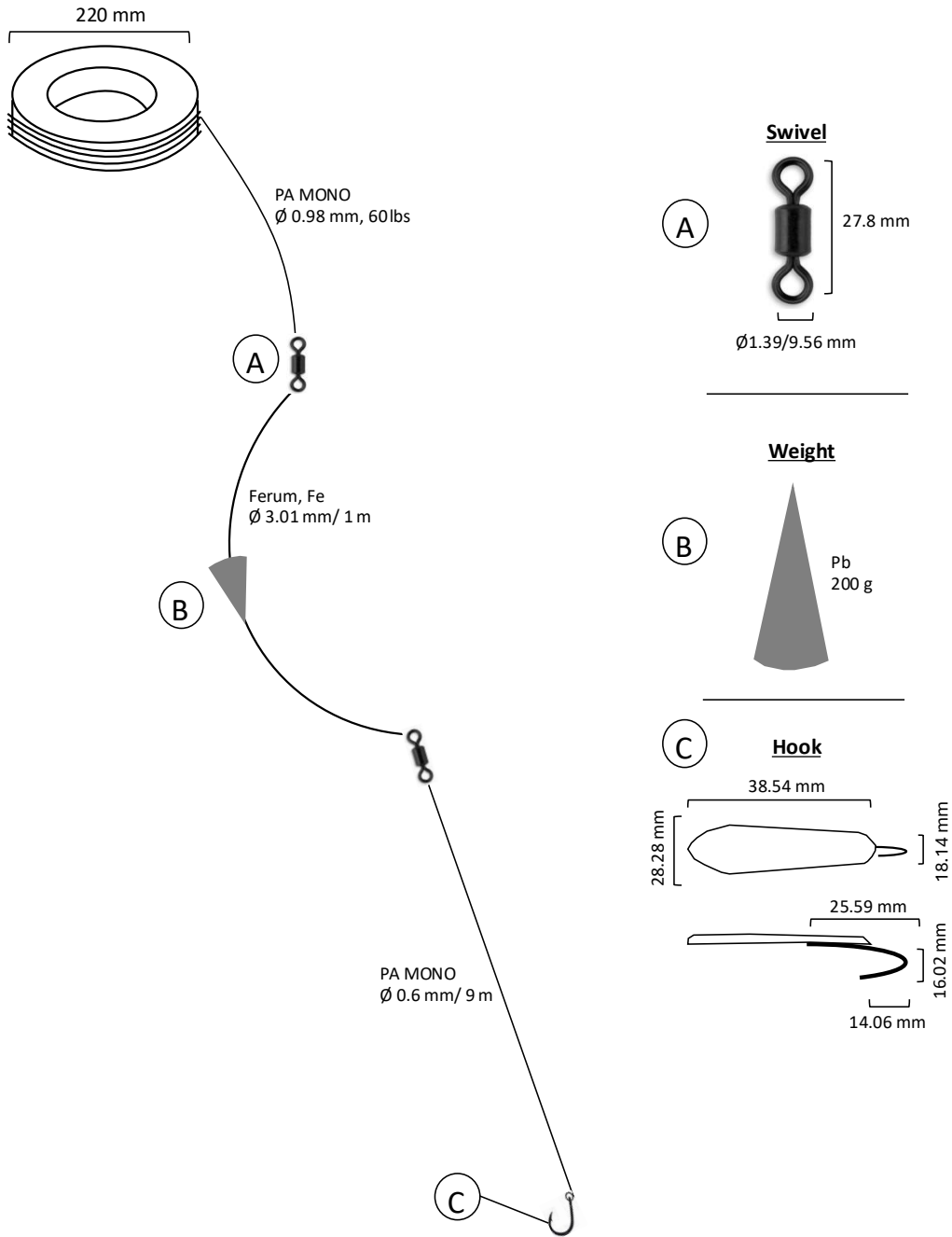


Figure 2b.: Technical attributes of tuna handline in Semporna

Types of Gear: Tuna Handline

Location : Semporna

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

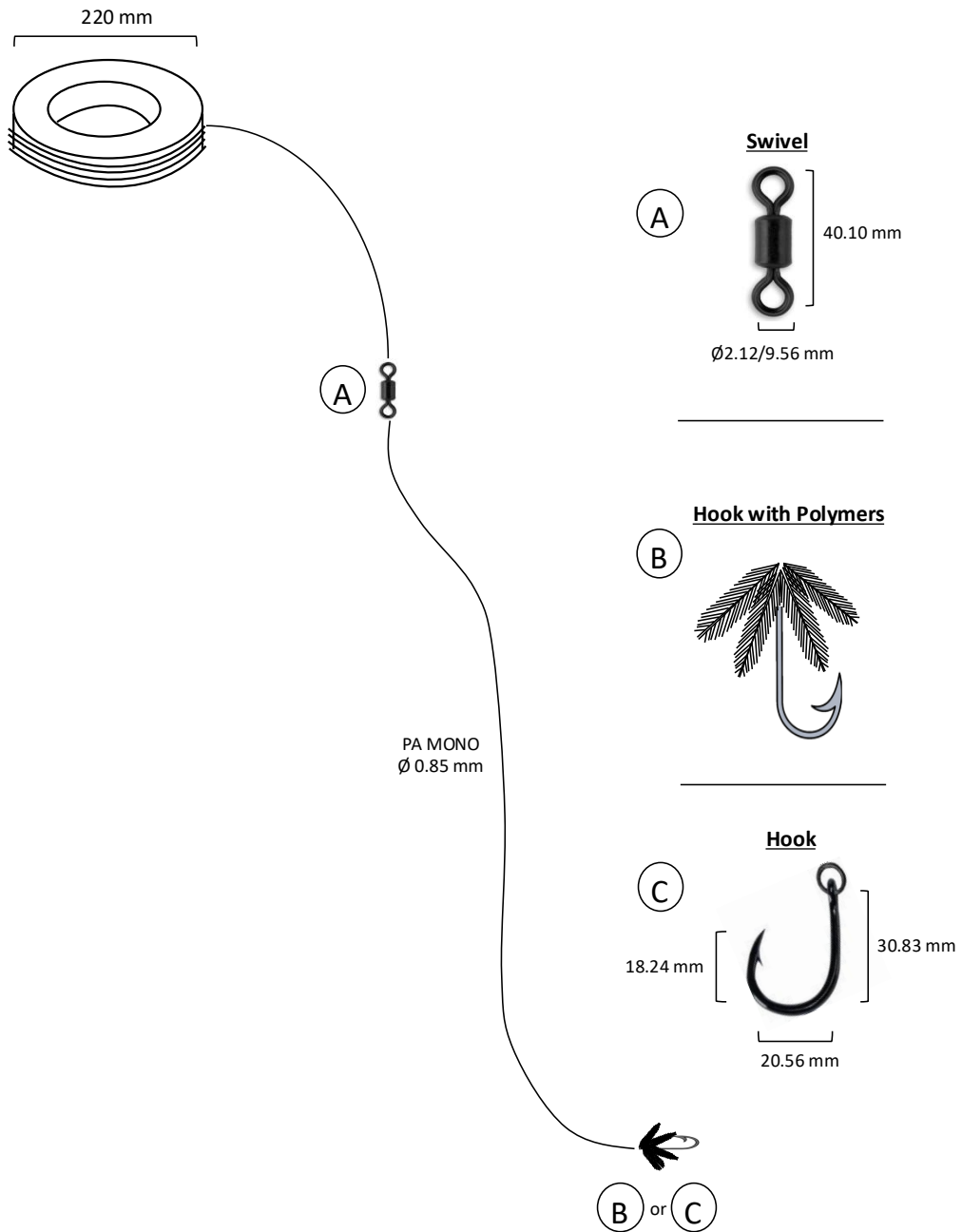


Figure 2c.: Technical attributes of tuna handline in Semporna

Types of Gear: Tuna Handline

Location : Labuan

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

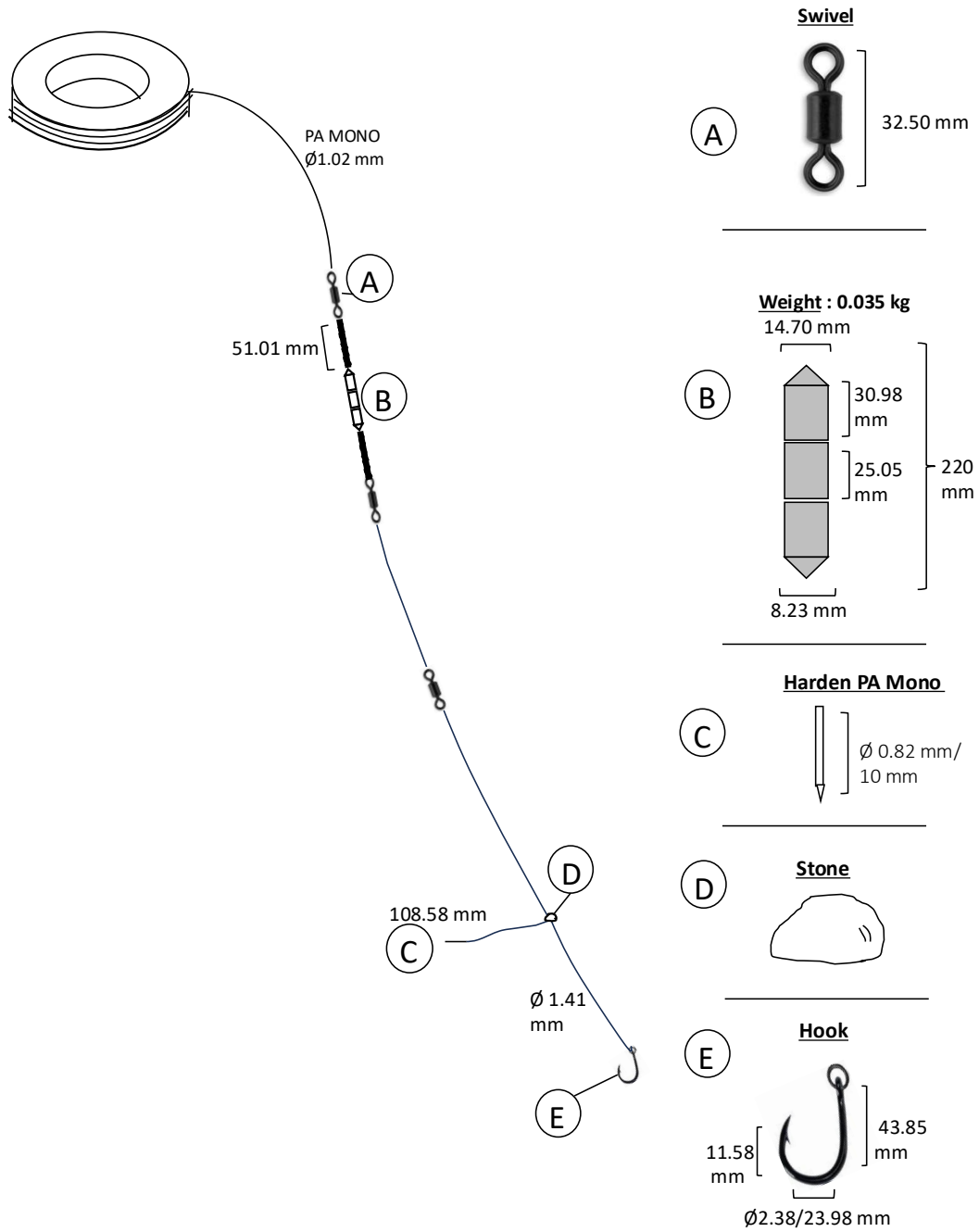


Figure 3a.: Technical attributes of tuna handline in Labuan

Types of Gear: Tuna Handline

Location : Labuan

Target species : Smaller size Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack

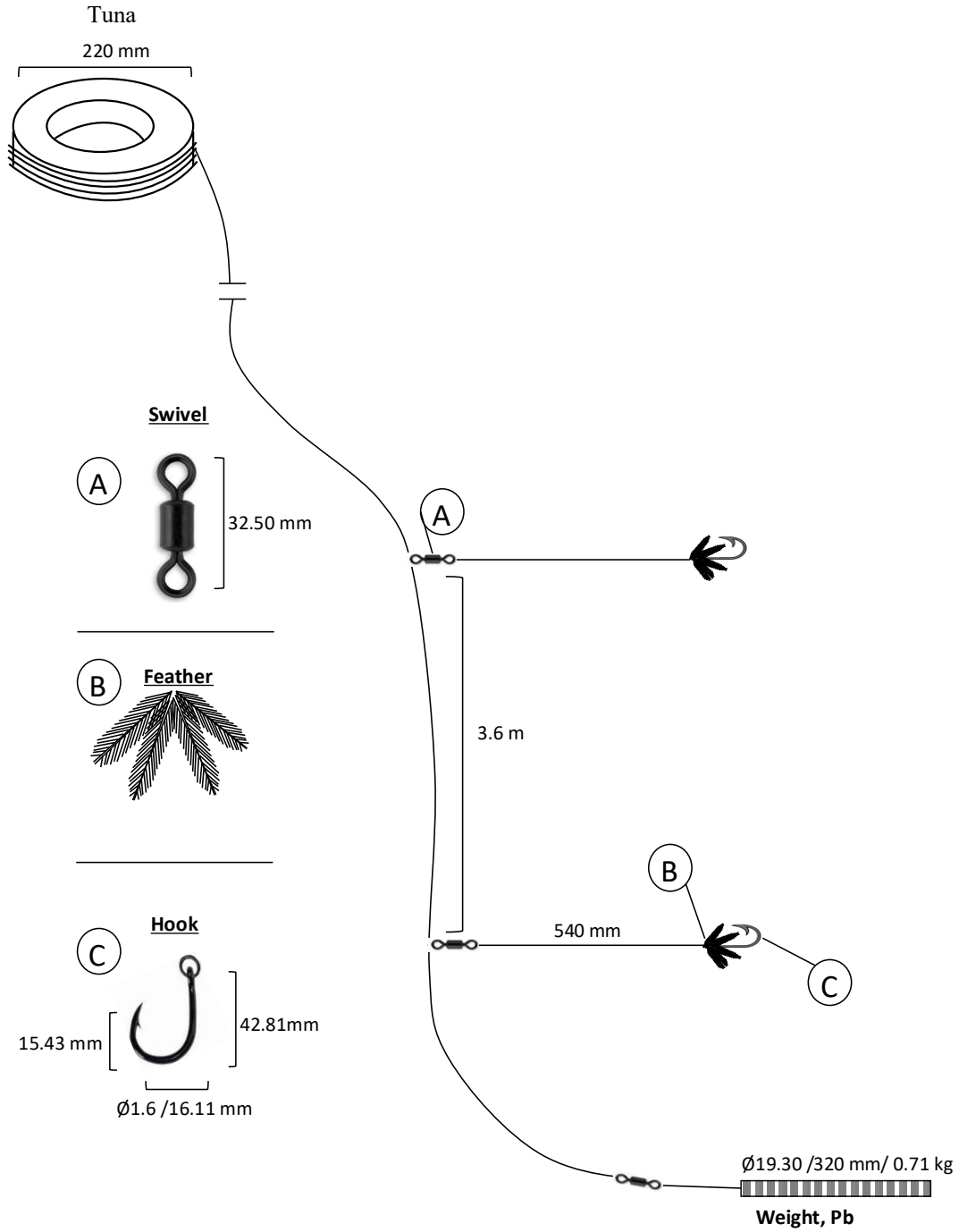


Figure 3b.: Technical attributes of tuna handline in Labuan

Types of Gear: Tuna Handline

Location : Labuan

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

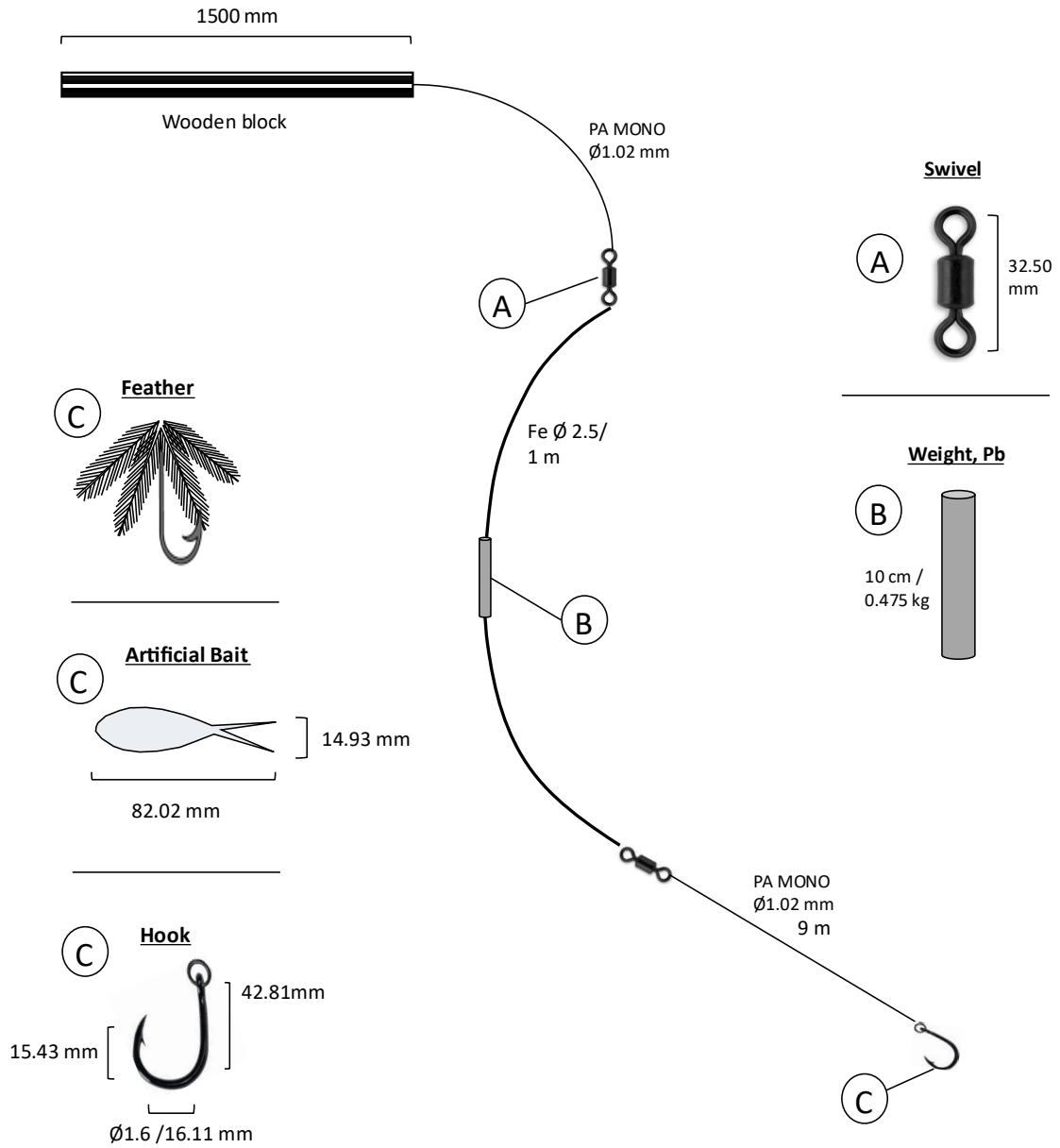


Figure 3c.: Technical attributes of tuna handline in Labuan

Types of Gear: Tuna Handline

Location : Labuan

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

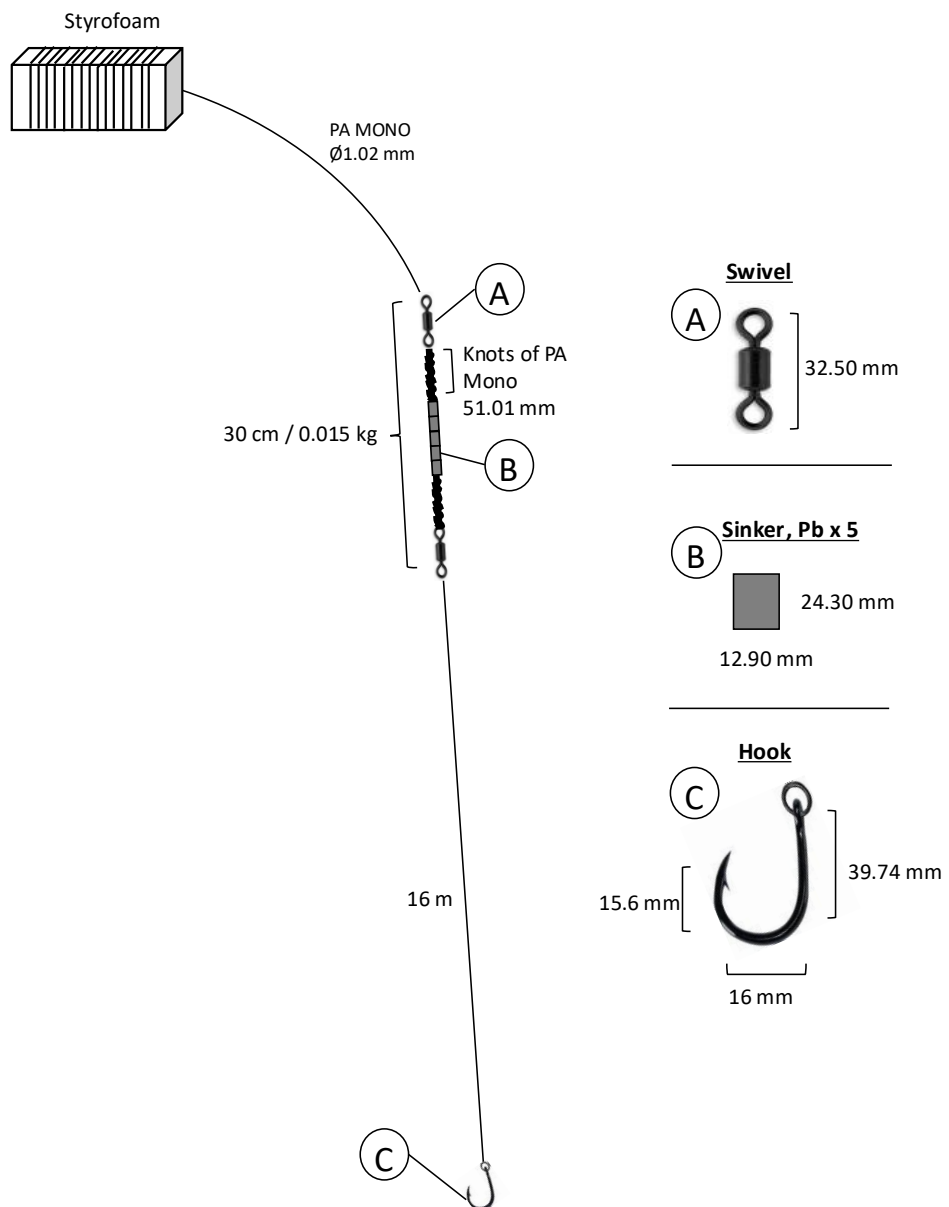


Figure 3d.: Technical attributes of tuna handline in Labuan

Types of Gear: Tuna Handline

Location : Kota Kinabalu

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

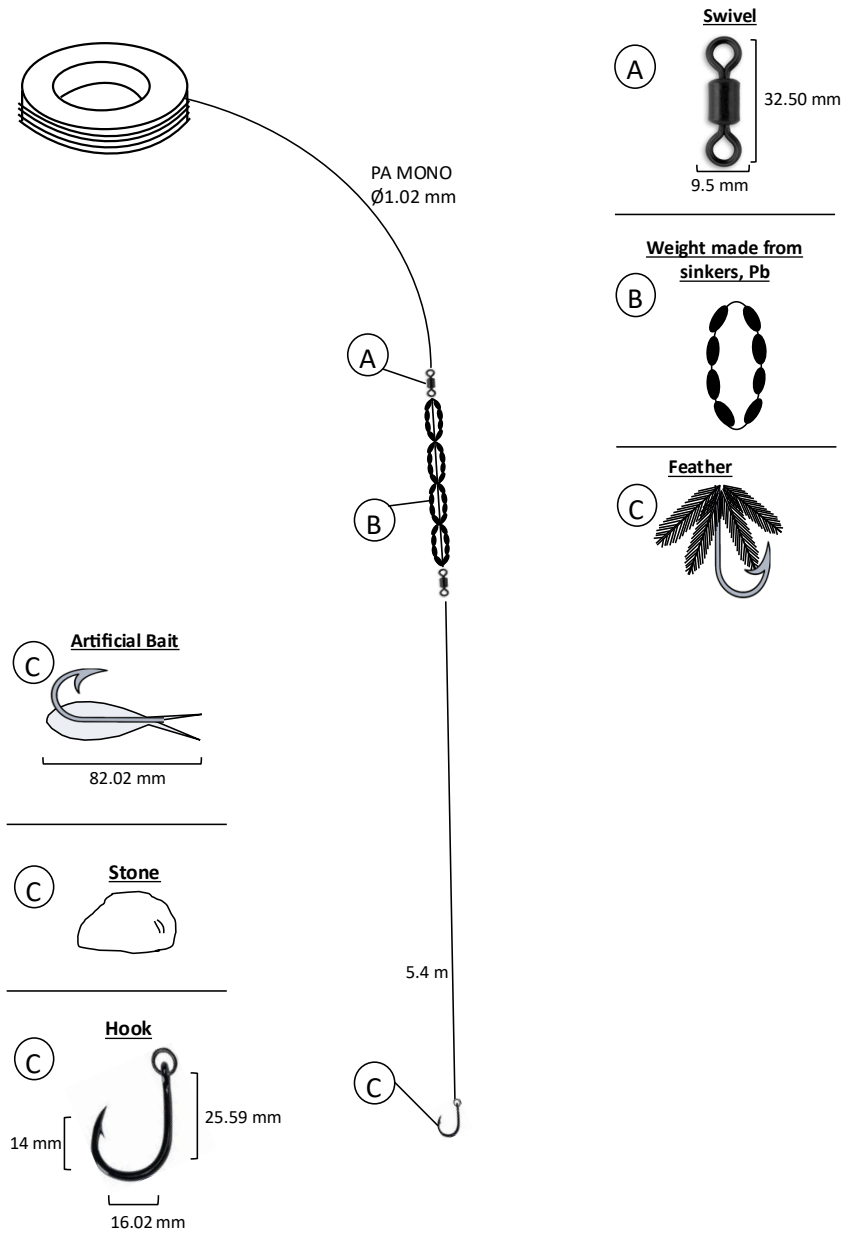


Figure 4a.: Technical attributes of tuna handline in Kota Kinabalu

Types of Gear: Tuna Handline

Location : Kota Kinabalu

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

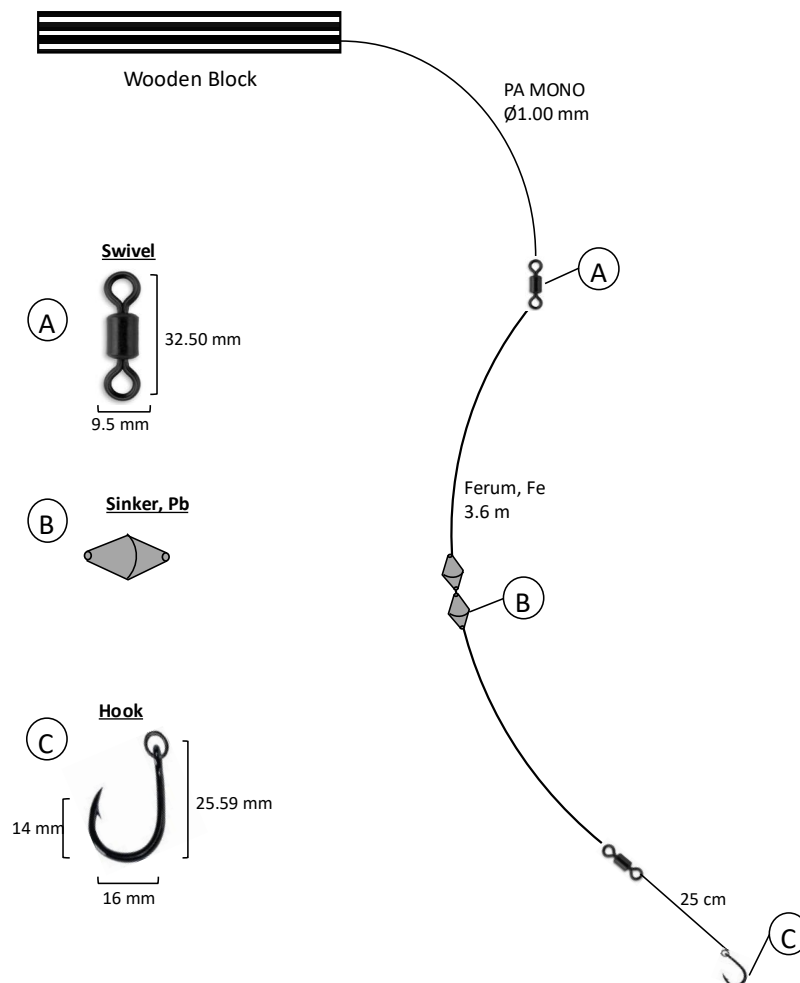


Figure 4b.: Technical attributes of tuna handline in Kota Kinabalu

Types of Gear: Tuna Handline

Location : Kota Kinabalu

Target species : Yellowfin Tuna, Bigeye Tuna, Albacore Tuna and Skipjack Tuna

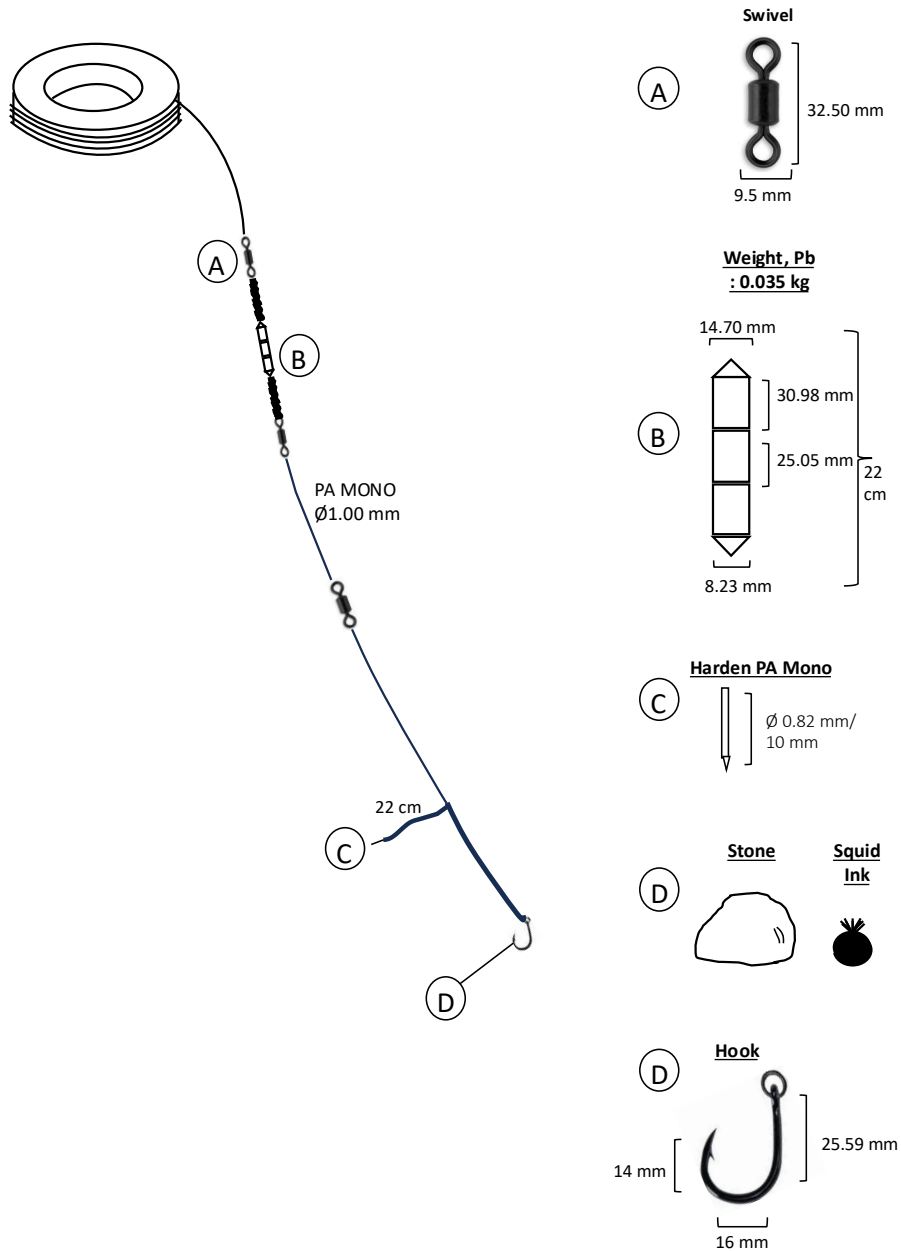


Figure 4c.: Technical attributes of tuna handline in Kota Kinabalu

Handlines Operation

Table 2 presents a comparison of tuna handline fishing operations by tuna fishermen in three key locations in Sabah and the Federal Territory of Labuan. The main fishing areas in Semporna are concentrated around FADs, or *payao* located approximately 12 nautical miles from Mabul Island and 3 nautical miles from Sipadan Island. In contrast, fishing operations in Kota Kinabalu take place between 120 and 140 nautical miles offshore, while operations in Labuan are conducted 90 nautical miles from the port. In most cases, all tuna fishing areas are located around artificial FADs installed by the fishermen themselves. In Kota Kinabalu, one fisherman reportedly owns around 40 FAD units, with a total fabrication cost of RM12,000 per FAD.

Local FADs in Southeast Asia are generally regulated through a combination of national fisheries legislation and regional fisheries management organization measures such as limits on FAD deployment, spatial–temporal closures, and the adoption of biodegradable or non-entangling designs yet their ownership often remains informal, whether private or communal, and is poorly documented. This lack of clear ownership contributes to accountability gaps, while increasing FAD density has been linked to ecological impacts including higher juvenile tuna mortality, increased bycatch of non-target species, alterations in fish behaviour and migration patterns, and the accumulation of marine debris (Dagorn *et al.*, 2013). Further empirical validation is needed to confirm these hypotheses and prevent the overstatement of results.

Table 2: Comparison of tuna handline fishing operations at three locations in Sabah and W.P. Labuan

Operation/ Location	Semporna	Kota Kinabalu	W.P Labuan
Fishing Area (nautical mile, NM)	12 NM from Mabul Island; 3 NM from Sipadan Island	120–140 NM from Kota Kinabalu	90 NM from port
Presence of FADs	✓	✓	✓
Number of FADs	NA	40 units	NA
Cost per FAD	NA	RM12,000	NA
Hook depth from Surface	40-50 m	30-40 m	55 m
Operation Time	Daytime (6 AM–6 PM)	Day/Night	Daytime
Time taken to land Tuna (>50kg)	1-2 hours	0.5-1 hour	0.5-1 hour
Water Depth	1500 m – 2000 m	1000 m	NA
Bait Types	✓ Fish & squid ✓ Artificial fish ✓ Squid ink	✓ Fish & squid ✓ Artificial fish ✓ Squid ink	✓ Fish & squid ✓ Artificial fish ✓ Squid ink
Trips per Month	3	3	4
Fishing Operations per Day	1	1-2	1
Water Conditions During Operation	NA	NA	NA
Main Target Species	Yellowfin Tuna Bigeye Tuna Albacore	Yellowfin Tuna Bigeye Tuna Albacore	Yellowfin Tuna Bigeye Tuna Albacore
Bycatch Species	Mahi-mahi Spanish Mackerel	Mahi-mahi Spanish Mackerel Black Marlin	Spanish Mackerel

Tuna fishing operations in Sabah are typically carried out regularly, with about three trips per month, while in Labuan, fishermen make up to four trips per month. Each trip usually lasts four to five days to maximize catch yield. In Semporna and Labuan, fishing is conducted once per day, whereas in Kota Kinabalu, it ranges from once to twice daily. Fishing activities begin after dawn, and end in the evening in Semporna and Labuan. In Kota Kinabalu, however, operations may take place during the day or night. The time taken to land a tuna fish per session varies from 30 minutes to two hours, particularly for tuna weighing over 50 kg. The fishing method involves lowering baited handlines to water depths

ranging from 1,000 to 2,000 meters, with hook depths from the surface recorded as 40–50 meters (Semporna), 30–40 meters (Kota Kinabalu), and 55 meters (Labuan).

Common bait types used by tuna handline fishermen in Sabah include fish meat cuts, squid, artificial fish, and squid ink. The fishing techniques and tuna fishing gear specifications employed by artisanal fishers in Malaysia exhibit notable similarities to those practiced in the Philippines. Mendoza *et al.* (2023) reported that traditional Filipino fishers capture tuna by attaching a lump of squid ink to a stone, which is then deployed alongside a hook. Upon release, the ink disperses, creating both a visual and olfactory stimulus that attracts tuna. Squid ink has been shown to contain amino acids that act as feeding stimulants for certain fish species (Derby *et al.*, 2013).

Additionally, the use of reflective coins as artificial lures by local fishers has demonstrated effectiveness in attracting tuna. Tunas are highly sensitive to light (Fritsches, 2002) and are drawn to the reflective properties of artificial lures that mimic the coloration of predatory fish. This was corroborated by Tauladani *et al.* (2013), who found that catch rates with artificial lures exceeded those obtained with natural baits such as fish flesh. In Semporna, a subset of tuna handline fishers has adopted the use of lead sinkers integrated with stainless steel wire, known as the Shutter. This innovation, also developed by Sururi *et al.* (2021) and trialed among fishers near Raam Island, Indonesia, proved both effective and environmentally preferable to traditional stone weights, which can damage marine habitats. Pointed design of the lead component reduces hydrodynamic drag during deployment. Subsequent evaluations by Sururi *et al.* (2022) demonstrated that the shutter substantially improves tuna catch efficiency compared to conventional methods.

Although sea conditions do not directly affect fishing operations, environmental factors such as weather particularly rain and storms have a significant impact on operational smoothness and fisher safety. The primary target species for tuna handlining in the waters off Sabah and Labuan include Yellowfin Tuna, Bigeye Tuna, and Albacore Tuna. Bycatch species include Mahi-mahi, Marlin, and Spanish Mackerel.

Handlines Economic Analysis

Table 3 shows the calculation of gross profit per trip for tuna handline fishermen in Sabah and the W.P Labuan. The landed catch from each fishing trip varies by location. On average, the quantity of tuna landed is around 905kg, 5,500kg and 900kg per trip for Semporna, Kota Kinabalu and W.P. Labuan, respectively. The value of landed catch across the three locations ranges from RM7,240 (Semporna), RM44,000 (Kota Kinabalu) and RM7,200 (W.P. Labuan) with the average price per kg is RM8 (Personal communication, 2024).

Table 3: Average gross profit calculation per trip for tuna handline fishermen in Sabah and W.P Labuan

Item / Location	Semporna	Kota Kinabalu	W.P. Labuan
Sample size	n=20	n=4	n=6
Catch weight (Kg)	905	5,500	900
Catch value (RM)	7,240	44,000	7,200
Total operating cost (RM)	5,864	28,550	5,029
Petrol/ Diesel	1450	4500	1498
Food	-	1500	300
Wages/ Salary	4264	21,000	2,971
Ice	150	1200	260
Bait/ Others	-	350	-
Operating cost margin	81%	65%	70%
Gross profit per trip (RM)	1,376	15,450	2,171

The Kruskal-Wallis test revealed significant differences in catch weight and catch value between all locations involved ($p = 0.00193$, $p < 0.05$). Further Dunn's post hoc test revealed that there were significant differences in catch weight and catch value between Semporna-Kota Kinabalu and Kota Kinabalu-W.P Labuan. However, there was no significant difference between Semporna-Labuan. The wide range of catch values reflects the inherent unpredictability of the tuna industry, which is highly dependent on seasonal fluctuations and biological factors. Despite the growth potential of Malaysia's tuna industry, these findings highlight a critical need for improved post-harvest handling and more equitable profit distribution to ensure the socio-economic sustainability of small-scale fishers in East Malaysia (Department of Fisheries Malaysia, 2019).

The estimated operating costs range from RM5,864 (Semporna), RM28,550 (Kota Kinabalu) and RM5,029 (W.P. Labuan) with operating cost margins 81%, 65% and 70% respectively. The high proportion of variable costs (fuel, bait, and labour) relative to gross revenue results in narrow profit margins, substantially increasing the financial vulnerability of fishers in Semporna, Kota Kinabalu and W.P Labuan. This aligns with global trends where fuel and labour typically constitute the largest share of variable fishing costs (Lam *et al.*, 2011). The lowest gross profit per trip recorded for fishermen in Semporna is approximately RM1,376, while fishermen in Kota Kinabalu earned the highest profit at RM15,450 per trip. Meanwhile, the gross profit for fishermen in W.P. Labuan is close to that of Semporna, with RM2,171. These variations are often attributed to the logistical advantages of larger hubs like Kota Kinabalu, where established supply chains allow for more competitive pricing and lower relative overheads compared to rural districts (Albat *et al.*, 2014).

CONCLUSION

This study underscores the significant diversity in tuna handline fisheries across Sabah and W.P. Labuan, where variations in vessel capacity and gear technology directly influence both operational reach and economic viability. The findings highlight that Kota Kinabalu serves as a primary hub for industrial-scale handline operations, utilizing higher horsepower engines (350 HP) to access distant fishing grounds, which translates to substantially higher catch volumes (5,500kg) and gross profits (RM 15,450) compared to the more localized artisanal operations in Semporna and Labuan. Technically, the integration of C-shaped hooks and innovative lures like squid ink and reflective coins demonstrates a strategic alignment with both capture efficiency and ecological sustainability. However, the high operating cost margins (65%–81%) driven largely by fuel and labour reveal a precarious economic landscape for smaller-scale fishers who remain vulnerable to seasonal fluctuations and market middlemen. To ensure the long-term socio-economic sustainability of Malaysia's tuna industry, it is imperative to address these disparities through improved logistical support, standardized data recording for vessel capacities, and the implementation of more equitable marketing frameworks that protect the livelihoods of fishers in rural landing sites.

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