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Fuel Saving Model on Seine Net Boats in Palabuhanratu

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***Abstract*— Fuel oil is a critical input for seine net fishing in Palabuhanratu, yet its rising cost imposes a heavy burden on fishers and boat owners. Although fishers intuitively adjust engine power to reduce fuel use, the effectiveness of these practices remains unclear due to limited data. This study examines fuel consumption patterns of seine net boats and explores potential savings strategies. Data was collected on daily fuel use, vessel speed, trip duration, and operating distances across boats with engines of different ages. Results show that fishing trips follow eight distinct phases: preparation, outbound steaming, setting, hauling, fish hunting, resting, inbound steaming, and berthing. The highest fuel use occurs during fish hunting as well as outbound and inbound steaming, where high speeds and long durations dominate. Engine age strongly influences efficiency: a 6-month-old engine achieved a specific fuel consumption (SFC) of 328.42 g/kWh, compared to 499.33 g/kWh for a 7-year-old and 873.41 g/kWh for a 12-year-old engine. Simulation of reduced speeds during fuel-intensive phases suggests potential savings of 1.7%–21.7%, without compromising operational feasibility. These findings highlight the importance of managing vessel speed and engine condition to optimize fuel efficiency in seine net fisheries.**

Keywords— Fuel efficiency, onboard engine, speed, fuel consumption.

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I. INTRODUCTION

Fuel oil is an organic compound essential for the combustion process, facilitating energy generation [1]. It serves as a critical component in motorized vehicles, including fishing vessels [2]. As a non-renewable energy source, fuel oil consumption is increasingly pertinent, influencing the availability of fuel resources in Indonesia [3].

Elevated fuel consumption has significant economic ramifications. National oil reserves are projected to deplete within 10-15 years if alternative energy sources are not pursued [4], leading to an inevitable increase in fuel prices in Indonesia. This situation imposes financial strain on fishers and vessel owners whose livelihoods are contingent upon fishing activities. Rosmah [5] supports this assertion, indicating that high fuel prices are a contributing factor to fishers ceasing their operations due to the prohibitive costs of fuel. Additionally, research by Almuzani [6] reveals that operational costs for fishers or vessel owners comprise 70% of total vessel operational expenses, predominantly allocated to fuel purchases. Gusti [7] also mentioned that one of the key challenges ship owners have to deal with is accurately determining the amount of fuel consumption and the associated fuel costs, which can significantly impact their overall operating expenses.

In Indonesia, fishing operations are predominantly characterized by small-scale fisheries, which account for 90% of the total fishers population, primarily engaging in coastal fishing activities [8]. Small-scale fishers are defined as those who catch fish to meet daily subsistence needs, either without a fishing vessel or utilizing vessels with a maximum size of 10 GT [9].

Palabuhanratu is a notable centre for small-scale capture fisheries in Indonesia. According to annual data from PPN Palabuhanratu in 2020, there are 371 fishing vessels under 10 GT, 80 vessels sized 11-20 GT, and 61 vessels exceeding 20 GT operating in the waters of Palabuhanratu. Smaller vessels, so called boats operated in the region are equipped with various fishing gear including seine net, lift net, gill net, and trammel net. Those boats typically run a one-day fishing operation. For a one-day fishing trip, fishers commonly bring their own supplies, resulting in operational costs being entirely allocated to fuel. On average, a seine net boat consumes between 66 to 108 litres of fuel per trip, lift net fishing is responsible for 29 to 42 liters, trammel net boat burns 30 to 60 litres, and bottom gillnet boats consume between 8 to 10 litres per trip [10].

Seine net boats or seine netters are identified as the most fuel-intensive among fishing boats. Pahlevi [11] indicate that boats in Palabuhanratu mostly exhibit issues related to the misalignment of its main dimensions with engine power except for seine netters. This suggests that while seine net boats are appropriately powered, they still exhibit high fuel consumption rates.

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The volatility and general upward trend in fuel prices exacerbate the economic challenges faced by fishers. The substantial costs incurred by fishers and boat owners present a significant issue, as expenditures on fuel do not correlate with stable fuel pricing [12]. Effective management of fuel consumption in fishing vessels is crucial to enhance fuel efficiency and mitigate the financial burden on fishers or boat owners. Davie [13] stated factors that affect fuel consumption are vessel size, age, dan condition, engine power, vessel speed and gear configuration, and nature and environmental factors, such as sea state and weather condition.

Research conducted by Kurniawati [14] indicates that seine net boats can achieve fuel savings by shutting down engines during hauling and optimizing engine power settings to regulate fuel consumption. While seine net fishers have implemented fuel-saving measures, their effectiveness remains inadequately evaluated. Concurrently, rising fuel prices and fluctuating catch yields present additional challenges. The scarcity of information regarding fuel consumption patterns hinders fishers and vessel owners from developing measurable fuel-saving strategies. If these conditions persist, there is a risk of declining incomes for fishers. Therefore, to aid fishers in implementing quantifiable savings measures, it is imperative to conduct research on fuel consumption patterns in seine net boats.

Given this context, the investigation of fuel oil consumption patterns and the formulation of savings strategies for seine net boats in Palabuhanratu is warranted. The objectives of this study are to identify the fuel consumption patterns of seine net boats in Palabuhanratu and to devise effective fuel-saving strategies. The methodological approach involves the collection of data on daily fuel consumption, vessel speed, and trip duration for seine net boats, which will be subjected to mathematical analysis to formulate efficient fuel-saving measures. This research aims to provide valuable insights into fuel consumption patterns for seine net boats in Palabuhanratu.

II. METHOD

The research was conducted from July to August 2024 at the Palabuhanratu Fishing Port, located in Sukabumi, West Java. The geographical context of the research site is illustrated in Figure 1. The tools employed in this research included notebooks and stationery for recording observational data, tachometers to measure vessel speed during fishing operations, stopwatches to accurately calculate the duration of trips, and GPS devices to document the geographical locations of fishing activities. For data processing, laptops were utilized along with Microsoft Office applications to organize and analyze the collected data effectively.

This study commenced by observing fishing operations alongside fishers. Data collection was conducted using three distinct methods: (1) Observations were made under existing fishing operation conditions, (2) Simulations were performed at varying speeds based on the power settings identified in the first method, and (3) Data was collected at different Revolutions Per Minute (RPM) settings. Following the data collection phase, the data was processed using Microsoft Office applications, after which a thorough data analysis was conducted.

Data collection involved both observational techniques and interviews. Researchers participated in fishing operations with seine net boats fishers in the Palabuhanratu Waters. Observations aimed to gather information regarding fuel consumption, the duration of the vessel's trips, and the operational time of the engine. Interviews were conducted to collect data on the size of the vessels, the age and type of the engines, and the engine power utilized during fishing operations.

The determination of the sample of fishing vessels and respondents in this study utilized the accidental sampling technique within the seine net group. This approach was adopted due to the uncertainty regarding the number of seine net boats engaged in fishing operations at the time of data collection. A total of three vessel samples were selected, each representing different ages and engine brands, to facilitate a comparative analysis of fuel consumption based on these variables. The results of the observations were systematically recorded, focusing on several key aspects, which are detailed in Table 1.

TABLE 1
SEINE NET BOATS OBSERVATION

Activity	Duration (Minutes)	Engine Condition	Engine Power	Speeds (knots)
Start				
…	…	…	…	…
…	…	…	…	…
Finish				

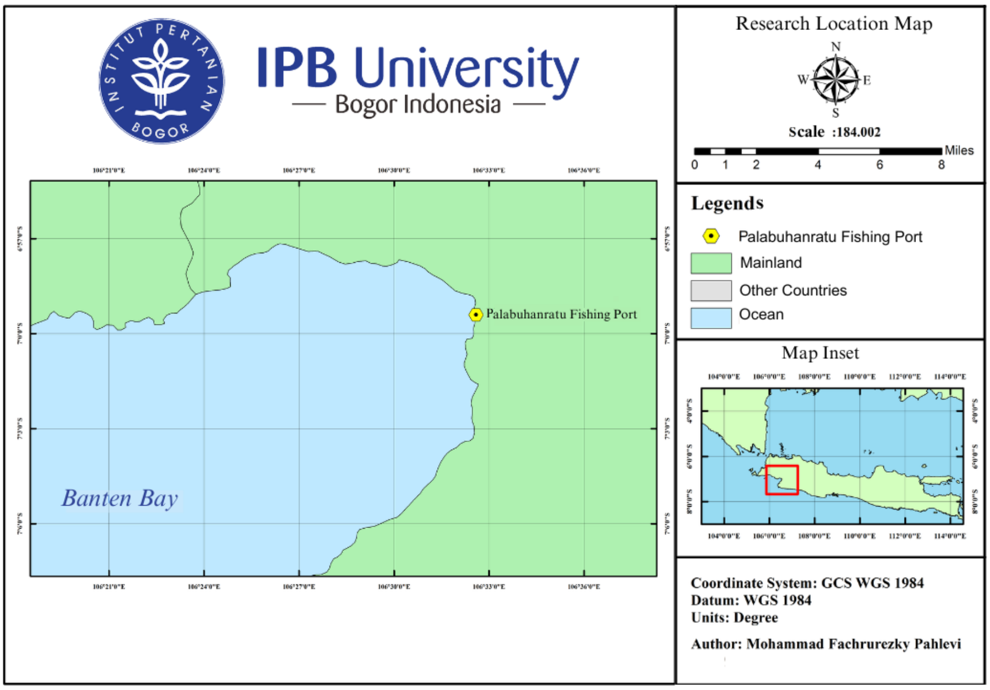


Figure 1. Research Location, in Palabuhanratu, Sukabumi District.

The collected data is subsequently processed through mathematical calculations to determine the fuel consumption values of the fishing vessels. Specific Fuel Consumption (SFC) serves as a critical parameter in engine operation, reflecting the economic efficiency of an engine. Understanding SFC allows for the assessment of the amount of fuel utilized to generate a specific amount of power over a given time interval [6]. Additionally, Monasari [15] noted that SFC can be interpreted as a measure of the efficiency with which fuel supplied to the engine is converted into output power.

As stated by Kurniawati [14], fuel consumption (litres/hour) can be mathematically expressed as a function of speed and a constant coefficient. This implies that fuel consumption during a fishing trip can be calculated if the time and fuel consumption at idle speed are known. The idle speed value is assumed to be 0.5 litres/hour, based on the average fuel consumption observed in traditional vessels in the study conducted by Tumigolong [16]. This value is then incorporated into the mathematical equation for fuel consumption as outlined in Kurniawati's research [14]:

$$Q_{fsum} = \sum_{i=1}^{n} \left(Q_{fo} + k v_{si}^{3}\right) . t_{si} \quad (1)$$

with:

$Qfsum$ = fuel consumption in fishing trip
Qfo = idle speed of the ship
k = constant coefficient
vs = speed
ts = time

The data obtained were subsequently analyzed using descriptive methods to address the objectives of this study. The first objective involved creating graphs and diagrams to illustrate the speed of the vessel throughout various activities during the fishing trip, from departure to return. This analysis aimed to determine the duration of engine usage and the specific fuel consumption during a single trip. The second objective focused on calculating the Specific Fuel Consumption (SFC) value, which serves as a basis for formulating fuel-saving strategies for seine net boats in Palabuhanratu. The SFC value is significant as it provides insight into the efficiency of fuel consumption by the engine.

III. Results and Discussion

A. Characteristics of Seine Fishing Vessel at PPN Palabuhanratu

As of 2023, there are 45 seine net boats operating in PPN Palabuhanratu (Palabuhanratu Fishing Port Data). These vessels are categorized as small-scale fisheries according to Law No. 7 of 2016, as they measure 4 Gross Tonnage (GT). Fishing operations on seine net boats are typically conducted as one-day trips, from 06:00 am to 18:00 pm. Generally, these vessels operate within the Palabuhanratu Bay area, ranging from the vicinity of the steam power plant and Jampang to Banten Bay and the Bayah area. The average dimensions of seine net boats in Palabuhanratu are approximately 12 meters in length, 1 meter in width, and 1 meter in depth. These vessels are primarily constructed from wood and are often coated with protective materials such as epoxy or resin. A depiction of a seine net vessel can be seen in Figure 2a.

In terms of propulsion, seine net boats in Palabuhanratu are equipped with 2-stroke Yamaha outboard engines with a power output of 40 HP (Figure 2b), using gasoline as fuel. The choice of a 40 HP engine is driven by the need for speed and power, enabling effective maneuvering during fishing operations and facilitating access to desired fishing locations. Kurniawati [17] stated that the vessels for seine net in Palabuhanratu need to produce good maneuverability rather than high towing power. Fishers typically carry 3-4 jerry cans of gasoline per trip, with each jerry can having a capacity of 30 liters. This allows for a total fuel capacity of 90-120 liters per trip. The specifications of the engine used are presented in Table 2.

Figure 2. a) Seine net boat in Pelabuhan; b) Yamaha outboard engines with a power output of 40 HP.

TABLE 2.
ENGINE SPECIFICATIONS USED ON THE SEINE NET BOATS AT PALABUHANRATU FISHING PORT

Component	Specification
Engine Brand	Yamaha 40 HP
Engine Type	2-Cylinder
Fuel	Gasoline
Maximum Engine Power	4500 – 5500 rpm
Fuel Consumption	20,0 l/h @5000 r/min

B. Engines on Seine net boats

The seine net boats operating in Palabuhanratu conduct fishing operations that are divided into several distinct activities, including loading supplies, departing for fishing grounds, net setting, hauling, fishing (steaming), returning to port, and docking. The determination of fishing grounds is primarily the responsibility of the skipper, who relies on information regarding fish resources obtained from other vessels, as well as personal experience and knowledge of seasonal fishing patterns. Observations were conducted on three seine net boats, each representing different engine age categories: less than 5 years, between 5 to 10 years, and over 10 years. Specifically, the observed engine ages were 6 months, 7 years, and 12 years.

During the study, the vessels typically depart in the morning around 06:00 a.m. and return approximately at 06:00 p.m.. Fishing operations commenced with the loading of supplies and warming up the engine. Throughout the loading phase, the crew and captain ensured that all necessary supplies were onboard while the engine idled. On average, a seine net vessel in Palabuhanratu carries 3-4 jerry cans of fuel, with each jerry can containing 30 liters of gasoline and 1 liter of oil. Consequently, the total fuel capacity ranges from 90 to 120 liters of gasoline and 3 to 4 liters of oil. After the loading process is completed, the vessel departs for the fishing area, operating at an average engine power of 50% of its maximum capacity, achieving an average speed of 4 knots. The targeted fishing areas include Bayah Bay, Ujung Genteng, Jampang, Palabuhanratu Bay, and regions surrounding the PLTU. The selection of these fishing areas is informed by reports from other vessels regarding schools of fish. The captain navigates to the fishing grounds without the aid of navigation tools, relying instead on information from other vessels and his expertise in identifying fish presence. Wibawa [18] noted that Indonesian fishers often utilize natural signs for fishing.

Upon arrival at the fishing area, the captain instructs the crew to set the net by casting it on the left side of the vessel in a circular manner, with the engine running at full speed. This technique is employed to effectively trap the target catch of fish. The time required for setting the net varies by the age of the vessel's engine. For vessels with a 6-month-old engine, the setting time is 8 minutes, and the average setting speed is 7.06 knots. In contrast, a vessel with a 7-year-old engine also takes 8 minutes to set the net, but its average setting speed is slightly lower at 7 knots. Notably, a vessel with a 12-year-old engine has a quicker setting time of 5 minutes, with an average speed of 6.37 knots.

Once the setting process is complete, the crew begins the hauling operation by pulling in the net. Typically, the engine is turned off during this process; however, there are instances when the engine is left idling. Keeping the engine running in idle allows for a quick transition to the next setting when the target catch is visible again. The average time taken for the hauling process differs among the vessels. A vessel with a 6-month-old engine takes approximately 16 minutes to haul, while a 7-year-old engine requires 26 minutes. In comparison, a vessel with a 12-year-old engine has an average hauling time of 23 minutes.

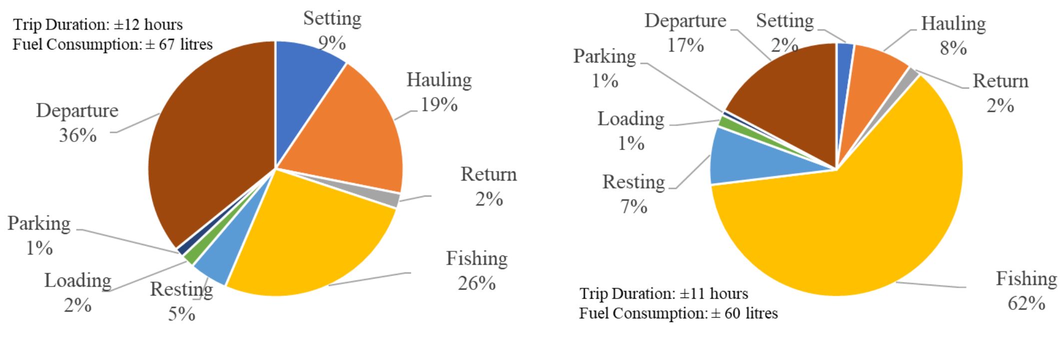
Fishing is resumed during the return trip if the weather and time permit. When the crew begins to observe schools of fish, the captain will instruct them to get ready for another round of fishing. This activity typically takes place in areas near the harbor pond or around the Palabuhanratu PLTU area. The conditions for setting and hauling the net remain consistent with previous operations. The catch is placed in available drums, and the setting and hauling processes are predominantly conducted in the regions surrounding the PLTU and near the harbor pond.

Once the captain decides to return, the vessel heads back to the PPN Palabuhanratu harbor pond, operating at about 50% of the maximum engine capacity. The average engine speed during the return journey ranges from 4.42 to 5.29 knots. Upon arriving at the harbor basin, the vessel parks and docks at the pier using approximately 25% of the maximum engine power, which translates to a speed of about 1.24 to 1.67 knots. This cautious approach is necessary due to the harbor basin being filled with other vessels, helping to avoid collisions. The values for time, speed, and other metrics for each activity on the vessel can be seen in Table 3.

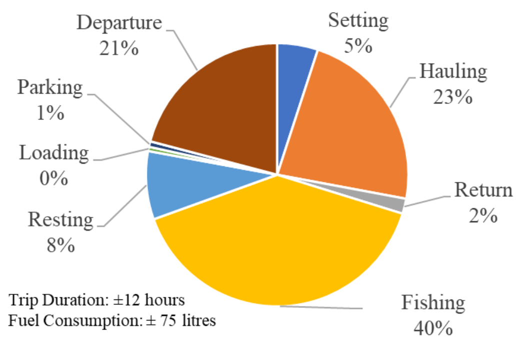
The three observed vessels demonstrate analogous fishing operational protocols, which encompass preparatory activities such as provisioning and engine warm-up, followed by navigation to the fishing grounds, fish searching, net setting, hauling, resting, and ultimately docking in the port pond area. Fuel consumption varied among the vessels, recorded at 67 liters, 60 liters, and 75 liters of gasoline, respectively. Notably, the vessel utilizing a 6-month-old engine exhibited the longest fishing trip duration, attributed to its targeting of more distant fishing areas. The most time-intensive phase across all vessels was the fishing process, driven by the collaborative efforts of the fishers and the captain, who relied on inter-vessel communication and experiential knowledge to identify fish school locations. The distribution of activities for the three vessels is depicted in Figure 3.

TABLE 3.
DURATION AND SPEED FOR EACH ACTIVITY ON THE SEINE NET BOATS IN PALABUHANRATU FISHING PORT.

Activity	Engine Ages			Engine Ages		
	6 months	7 years	12 years	6 months	7 years	12 years
	Duration (HH:MM:SS)			Speed (knot)		
Setting	01:08:22	00:15:57	0:35:35	7,06	7	6,37
Hauling	02:14:40	00:52:32	2:42:14	0,00	0,00	0,00
Departure	04:18:25	02:00:01	2:28:06	5,48	4,75	3,83
Fishing	03:10:09	07:08:13	4:41:26	6,69	5,70	4,98
Loading	00:12:27	00:10:36	0:03:40	0,00	0,00	0,00
Resting	00:34:55	00:52:17	0:59:26	0,00	0,00	0,00
Return	00:13:59	00:11:23	0:13:09	5,29	4,42	5,29
Parking	00:08:39	00:04:21	00:04:50	1,24	1,67	1,5



(a) (b)



(c)

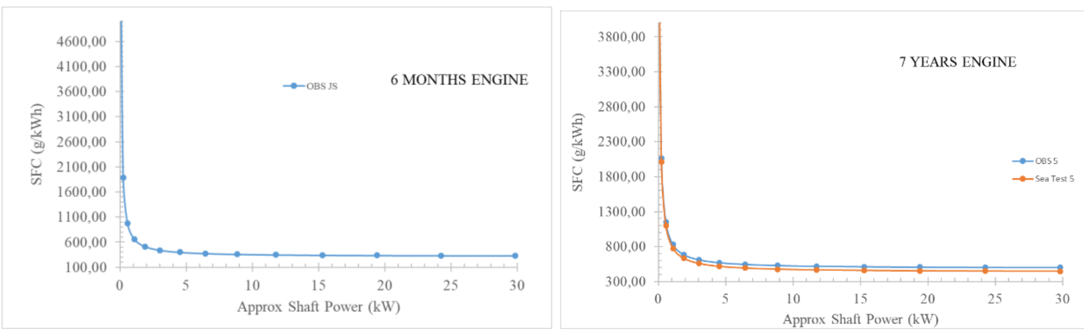
Figure 3. Distribution of activities for the three vessels. (a) 6 months; (b) 7 years; (c) 12 years.

C. Fuel Consumption of Seine net boats

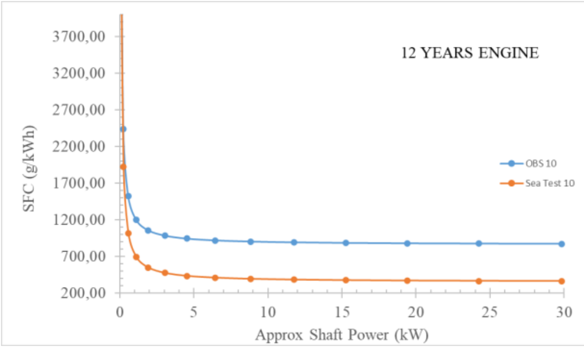
The assessment of fuel consumption in this study aimed to ascertain the specific fuel consumption (SFC) values for the observed vessels. Data collected during the observations were utilized to derive the constant value k necessary for the SFC calculations. Subsequent mathematical analyses were conducted to evaluate the fuel consumption rate for each vessel, leading to the determination of the specific fuel consumption values and the development of a mathematical model for each calculation. The graphical representation of the specific fuel consumption rate values is illustrated in Figure 4.

Specific Fuel Consumption (SFC) is a critical parameter utilized to quantify fuel efficiency in vehicles. The mathematical calculation of SFC involves assessing the rate of fuel consumption relative to engine performance over its operational lifespan. According to Monasari [15], SFC is defined as the ratio of fuel flow rate to the thrust (power) generated by the engine. Figure 4 illustrates the variation in SFC values across different engine ages, highlighting the influence of engine age on fuel efficiency. This observation is corroborated by Muziansyah [19], who noted that older engines tend to produce higher concentrations of CO emissions, indicating increased inefficiency. Rachman [20] further elucidates the correlation between gas emissions and fuel consumption, suggesting that older engines exhibit higher fuel consumption rates. In this study, a comparative analysis was conducted on SFC values under existing fishing operational conditions, supplemented by simulations of varying speeds without actual fishing activities. The results indicated that the 6-month-old engine achieved an SFC value of 328.42 g/kWh, the 7-year-old engine had an SFC of 499.33 g/kWh, and the 12-year-old engine recorded an SFC of 873.41 g/kWh. As noted by Monasari [15], a lower SFC value signifies more efficient fuel consumption, thus establishing that among the engines tested, the 6-month engine demonstrated the highest fuel efficiency, while the 12-year engine exhibited the lowest.

A notable disparity exists in the Specific Fuel Consumption (SFC) values between engines tested under actual operational conditions and those evaluated in speed simulations devoid of fishing activities. For the 7-year-old engine, the SFC value recorded under existing conditions was 499.33 g/kWh, whereas in simulation conditions without fishing operations, it was reduced to 446.35 g/kWh. This variation suggests the influence of additional factors on SFC values. Pambudi [21] indicate that the load carried significantly impacts fuel consumption levels, a sentiment echoed by Nurkhamin [22], who assert that workload is a critical determinant of fluctuations in fuel consumption. In operational settings, the vessel bears a heavier load, including a crew of 10-12 members, the catch from fishing, spare fuel, provisions, fishing gear, and auxiliary engines. Conversely, during speed simulation tests without fishing operations, the vessel's load is comparatively lighter due to the absence of these factors. For the 12-year-old engine, the difference in SFC values between existing conditions and speed simulations is pronounced, with an SFC of 873.41 g/kWh in operational conditions and 362.87 g/kWh in simulation conditions. This discrepancy is also attributable to the engine's capability to combust fuel efficiently. Syahrir [23] elucidate that the mass flow rate of fuel through the combustion system is pivotal for combustion efficiency, a parameter that can be adversely affected by the age of the engine.



(a) (b)



(c)

Figure 4. Specific fuel consumption (SFC) rate. (a) 6 months; (b) 7 years; (c) 12 years.

D. Fuel Saving Model of Seine Net Vessel

In the research conducted by Kurniawati [14], several strategies for reducing operational fuel costs were proposed, including the conversion of vessel construction to fiberglass, redesigning fishing units, and optimizing speed and fuel consumption management. This study specifically focused on developing a fuel-saving model for the seine net boats vessel in Palabuhanratu, emphasizing the management of speed and fuel usage. The rationale for this approach lies in the ability to mathematically analyze speed management and fuel consumption using the data collected in this study, facilitating a comprehensive assessment of potential fuel savings.

The calculation process for the fuel-saving model in this study involves systematically reducing the speed during the "Fishing" activity from maximum power to 50% by decrementing speed by 0.5 knots at each interval. This adjustment is based on the observation that maximum power is not always necessary during the fishing phase, as the vessel does not require full throttle while searching for target catches. In contrast, the "Setting" activity necessitates maximum speed to efficiently encircle the target catch. Research by Gusti [24] reveals that using low speeds on sailing can reduce fuel consumption but its benefits only apply if the vessel's total sailing time remains within the specified limit. Taskar [25] stated that low-steaming, along with the implementation of speed optimization methods, offers a practical solution that is relatively easy to adopt and does not demand substantial infrastructure investment. The fuel-saving model for each engine is detailed in Table 4, 5 and 6.

The fuel-saving models implemented in this study demonstrated that reducing and managing speed effectively decreases fuel consumption. For the 6-month engine, fuel savings reached up to 38,74%; for the 7-year engine, fuel savings can be 30,35%; and for the 12-year engine, savings were observed up to 37,06%. The speed reductions incorporated in these models considered the duration of fishing activities, revealing a clear relationship between speed and time: as speed decreases, the time required for fishing increases, and conversely, higher speeds result in shorter durations.

The fuel-saving model developed in this study provides fishers and ship owners with a viable strategy for fuel conservation through effective speed management. However, successful implementation of this savings formula requires collaboration and heightened awareness from the captain regarding responsible navigation practices. Kurniawati [14] highlighted that the adoption of a speed management-based savings model presents challenges, particularly in ensuring that the ship's captain comprehends the importance of controlling speed and operating the vessel's engine responsibly.

TABEL 4.
THE FUEL-SAVING MODEL FOR THE 6-MONTH ENGINE

Simulation Speed (knots)	Simulation Fuel (litres)	Simulation time (sec)	Fuel Efficiency (percent)	Real Fuel (litres)	Real Time (sec)
7,69	37,52	02:40:40	-51,88		
7,19	33,09	02:51:59	-24,14		
6,69*	29,78	03:10:09	0	29,78	03:10:09
6,19	25,11	03:19:34	20.79		
5,69	21,57	03:36:36	38,74		

*: average speed based on observation for the activity "Fishing"

TABEL 5.
THE FUEL-SAVING MODEL FOR THE 7-YEAR ENGINE

Simulation Speed (knots)	Simulation Fuel (litres)	Simulation time (sec)	Fuel Efficiency (percent)	Real Fuel (litres)	Real Time (sec)
6,3	56,62	04:44:15	-37,10		
5,8	48,60	05:09:03	-17,68		
5,3*	41,30	05:38:35	0	41,30	05:38:35
4,8	34,58	06:12:52	16,26		
4,3	28,76	06:56:44	30,35		

*: average speed based on observation for the activity "Fishing"

TABEL 6.
THE FUEL-SAVING MODEL FOR THE 12-YEAR ENGINE

Simulation Speed (knots)	Simulation Fuel (litres)	Simulation time (sec)	Fuel Efficiency (percent)	Real Fuel (litres)	Real Time (sec)
5,98	64,45	03:37:01	-30,84		
5,48	54,64	03:57:07	-10.93		
4,98*	49,26	04:41:26	0	49,26	04:41:26
4,48	37,57	04:49:41	23,73		
3,98	30,51	05:26:36	37,06		

*: average speed based on observation for the activity "Fishing"

IV. CONCLUSION

Fishing operations of a seine net boat simply consists of preparation at the port. sailing to fishing grounds. fish hunting - setting the gear - hauling the gear – fish handling repetitively. and sailing back to the port. The phase of sailing to fishing grounds and returning to the port as well as fish hunting phase are responsible for the highest fuel consumption during fishing operation of seine net. Accordingly. the simulation was set by decreasing the boat speed during those phases. while still considering the optimal speed and time of fishing operation. The research suggests that by doing so. fuel savings on seine net boats can reach between 1.7% and 21.7%.

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