Suitability of engine power for small-sized fishing boats at the Palabuhanratu Fishing Port

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Abstract. Since fuel is a significant item in fishing operation, its high price becomes a burden for fishers and boat owners so they have to improve the economic efficiency of fishing operation. This study reviews the suitability of the dimensions of fishing boats with the power of the engine to determine a strategy in addressing an issue in fuel consumption. The suitability was assessed by comparing the existing engine power with the theoretical power required by the boats and the amount of fuel carried onboard during their fishing trips with the theoretical amount of fuel needed. The results showed that most small-sized boats at Palabuhanratu had engines with power more than the requirement, except for wooden boats that used 40 PK outboard motor engines. Fishers tend to carry fuel 62.1% more than the theoretical requirement because of the use of larger engines and the needs to bring spare fuel.

1 Introduction

Fuel oil is the main input for the combustion engines [1] that are commonly used in fishing boats to generate propulsions. The availability of fuel for motorized fishing boats significantly determine fishing process, including small-sized fishing boats [2]. Fuel constitutes a substantial expense in fishing operation, i.e., 60% to 70% of the total operational cost [3]. The fuel consumption of fishing boats is directly linked to engine power [4], higher engine power results in more fuel usage. Consequently, the elevated operational expenses associated with the increase in fuel cost can impose significant financial burdens on fishers and boat owners.

In Indonesia, fishing industries are characterized by small-scale fisheries that engage fishers who operate small-sized fishing boats. According to Law Number 7/2016 on the Protection and Empowerment of Fishermen, Fish Cultivators, and Salt Farmers, small fishers are defined as those who catch fish to fulfil their daily needs.

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either use fishing boats or not, if they operate boats with maximum size 10 GT. The small-scale fisheries in Indonesia engage about 90% of the total number of fishers who mainly operate in coastal areas [5].

Palabuhanratu in the southern coast of West Java, is one of significant bases of coastal fisheries in Indonesia. In 2021, the fishing fleets registered by the fishing port authority consisted of fishing boats of 658 units of less than 10 GT, 80 units of 11-20 GT, and 61 units of larger than 20 GT. The fleets are dominated by fishing boats with one day fishing mode. As fishers bring their own personal supplies, the boat owners cover almost the entire operational cost for fuel [6]. The unstable fuel prices with an increasing trend make the boat owner in difficult economic situation. When fishers have difficulty in finding and buying fuel, fishers are forced to stop or cancel their fishing operation [7]. The boat owners must find options to improve fishing efficiency, i.e. reasonable cost of fishing operation when the price of the fuel is higher. If possible, excessive cost for fuel should be avoided or minimized. The small-scale fisheries tend to use engines with power higher than recommended power for their boats that leads to inefficiency in the fuel consumption and subsequent inefficient fishing operation [8, 9, 10]. The mismatch was due to the procurement process of the boats. The boat builders and boat owners did not have many options (or flexibility) in determining the size of the boats and boat engines. One of the first steps in identifying such options is reviewing the suitability of engine for fishing boats in relation to fuel consumption.

The aims of this research are: (1) to identify the diversity of fishing boats at Palabuhanratu Fishing Port with indicators of principal dimensions, engine power and fuel consumption, (2) to evaluation was carried out by analyzing the power of engines used by fishing fleets, principal dimensions of the boats, fuel consumption rate and the fuel carried onboard. This study ignores two factors that may affect fuel consumption, i.e., water and air resistance. This research provides some information that are useful to promote the efficiency of fishing operation in small-scale fisheries. The boat builders and boat owners can plan better boat size with proper engine power.

## 2 Methods

### 2.1 Data collection

The research was conducted by collecting data in March 2023 at Palabuhanratu Nusantara Fishing Port, Sukabumi, West Java. The main subjects of this research were fishing boats. The population of fishing boats was divided into 6 groups which were based on type of boat and power of its power: (1) 40 PK wooden boats (WB40), (2) 40 PK outrigger wooden-boats (WB40-or), (3) 15 PK fibreglass reinforced plastic (FRP) boats (FRP15), (4) 5.5 PK FRP boats (FRP5.5), (5) 30 PK diesel inboard-motorised wooden boats (WB30-d), and (6) 100-120 PS inboard-motorised wooden boat (WB120). The samples of 3-5 units for each boat groups were selected by accidental approach, i.e. unplanned – based on first encounter or presence. The sizes of the boats for each boat group were generally similar.

The principal dimensions of fishing boat samples were measured using tape measure and laser measure. Engine type and power were identified onboard. Fishers from affiliated boat samples were interviewed on duration of their fishing trips, fuel
consumption and the amount of fuel carried onboard. Additional information was obtained from interviews with fishers and boat owners from non-sampled boats. The interviews were stopped when no additional new information identified. Data on speeds and length of time the engine used were collected from some literature of earlier studies.

2.2 Data processing

The data were grouped according to the types of boats. Calculations were carried out to compare the power of the engines with the theoretical power requirement and to compare of the volumes of fuel carried onboard with the theoretical requirement of fuel.

The boat displacement (\( V \), volume), boat displacement (\( \Delta \), tonnes), indicated horsepower (IHP) and brake horsepower (BHP) are calculated with the following formulas:

\[
V = L_{wl} \times B_{wl} \times d \times C_b
\]

Where: \( L_{wl} \) = length of waterline, \( B_{wl} \) = breadth of waterline, \( d \) = draught, and \( C_b \) = block coefficient

\[
\Delta = V \times \rho_s
\]

Where: \( \rho_s \) = density of seawater

\[
IHP = \frac{\sqrt[3]{\Delta \times v^2}}{c}
\]

Where: IHP = indicated horsepower, \( \Delta \) = displacement (tonnes), \( v \) = boats speed (m/s), \( c \) = admiralty coefficient.

In this study, the admiralty coefficient was adjusted according to the length of fishing boat [11]. The admiralty coefficients for a wooden fishing boat of 7-9 meter-long was 50, wooden fishing boat of 10-13 m was 55, and 14-16 meter was 60. The theoretical engine power (\( P_t \)) is brake horsepower (BHP) which is calculated with the formula from Nomura and Yamazaki [14]:

\[
BHP = P_t = 0.8 \times IHP
\]

Difference in power (\( D_P \)) between installed engine (\( P_i \)) and theoretical power requirements (\( P_t \)) is calculated as:

\[
D_P = \frac{P_i - P_t}{P_t} \times 100\%
\]

Theoretical fuel requirement (\( F_t \)):

\[
F_t = F_r \times P \times t
\]

Where: \( F_r \) = fuel consumption rate (kg) [12], \( P \) = engine power (HP), \( t \) = trip duration or navigation excluding rest duration. \( F_r \) is 0.17 for petrol and 0.22 for diesel fuel.
Difference in theoretical fuel requirement \((F_r)\) and fuel carried on board \((F_c)\) is calculated as:

\[
D_F = \frac{F_c - F_t}{F_t} \times 100\% 
\] (7)

### 3 Results and Discussion

#### 3.1 Characteristics of the fishing boats

Based on type of fishing gear, the fishing boats in Palabuhanratu Fishing Port can be distinguished into several groups, i.e.: boat seiners, lift-net transportation boats, hand-liners, trammel netters, trollers, tuna longliners and gillnetters. These fishing fleets are commonly operated on a one-day fishing basis, either daytime or evening fishing. Based on their materials of construction, the boats can be distinguished into two groups, i.e., wooden boats and fiberglass-reinforced plastics (FRP) or FRP boats. The majority of the fishing boats have sizes less than 10 GT. Their sizes varied with length overall (LOA) of 8-16 m, widths of 1-4 m, and depths of 0.3-1.28 m (Table 1).

The boat sizes for each gear type boat were similar because the boat owners determine the boat dimension based on the existing boats of the size group. The power of main engine was selected on the basis of local habits, engine availability and spare parts in Palabuhanratu. Boat owners and fishers consider the outboard engines have some advantages over inboard motors, i.e. low fuel consumption and easy to repair. Diesel engines were chosen because of their power, longer engine life, and the prices were relative cheap.

<table>
<thead>
<tr>
<th>Boat types</th>
<th>Number of samples</th>
<th>Length (m)</th>
<th>Breadth (m)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB40</td>
<td>5</td>
<td>12.75-13.61</td>
<td>2.9-3.08</td>
<td>0.8-0.99</td>
</tr>
<tr>
<td>WB40-or</td>
<td>3</td>
<td>11.04-11.94</td>
<td>1.49-1.72</td>
<td>0.6-0.78</td>
</tr>
<tr>
<td>FRP15</td>
<td>5</td>
<td>8.9-12.01</td>
<td>1.2-1.56</td>
<td>0.3-0.6</td>
</tr>
<tr>
<td>FRP5.5</td>
<td>5</td>
<td>7.8-9.16</td>
<td>0.75-1.8</td>
<td>0.93-1.19</td>
</tr>
<tr>
<td>WB30-d</td>
<td>3</td>
<td>9.68-12</td>
<td>2.39-2.63</td>
<td>0.93-1.19</td>
</tr>
<tr>
<td>WB120</td>
<td>3</td>
<td>14.43-16.66</td>
<td>3.09-3.91</td>
<td>1.18-1.28</td>
</tr>
</tbody>
</table>

According to Indrayani et.al. [13] fishing fleets used by communities around Sukabumi, especially in Palabuhanratu, are divided into three categories based on the type of engine, namely boats without motors, boats with outboard motors, and motorboats. The type of engine power used by fishers varies based on the types of fishing gear and vessel used. Boat seiners consist of two boat types i.e., wooden boats and wooden outriggers boats that use outboard engines of 40 HP. Hand-liners consist of FRP boats with different engines, i.e. 15 HP engines and multi-purpose engines of 5.5 HP. Trammel netters are wooden boats powered by diesel engines (Jiandong 300 and Yanmar TF 300). The transportation boats for liftnets are wooden boats with diesel engines (Mitsubishi 120 PS and 4D31 100 PS).
3.2 Suitability of engine power and boat sizes

Based on the calculations of the IHP and BHP using Nomura and Yamazaki formula [14] and the admiralty coefficients, the power of fitted engines of the studies fishing boats in Pelabuhanrate are generally higher than the theoretical requirements (Table 2). Excessive power (identified as positive differences) is identified from 5 boat types (WB40, WB40-or, FRP15, WB30-d, and WB120). Negative difference is identified only for FRP5.5).

Table 2. Comparison between the power of fitted main engine and the theoretical required brake horsepower (BHP) for each vessel type

<table>
<thead>
<tr>
<th>Vessel types</th>
<th>Main engine power (HP)</th>
<th>BHP (HP)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB40</td>
<td>40</td>
<td>37.66</td>
<td>+5.86</td>
</tr>
<tr>
<td>WB40-or</td>
<td>40</td>
<td>19.59</td>
<td>+51.04</td>
</tr>
<tr>
<td>FRP15</td>
<td>15</td>
<td>8.28</td>
<td>+44.82</td>
</tr>
<tr>
<td>FRP5.5</td>
<td>5.5</td>
<td>5.92</td>
<td>-7.61</td>
</tr>
<tr>
<td>WB30-d</td>
<td>30</td>
<td>21.70</td>
<td>+27.66</td>
</tr>
<tr>
<td>WB120</td>
<td>100</td>
<td>43.77</td>
<td>+56.23</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>43.77</td>
<td>+63.52</td>
</tr>
</tbody>
</table>

The WB40 and FRP5.5 appear to have appropriate main engines as the difference is between 5-10% (Table 2). The range of BHP for FRP5.5 was 3.71-7.89 HP with an average of 5.92 HP. Compared to the current power, the main engines of the FRP5.5 were considered appropriate for the existing dimension.

The power of the main engines of WB40-or, FRP15, WB30-d, and WB120 was higher than the requirements. Excessive power for the main engines were identified for WB40-or, FRP15, and WB120 while moderate excessive power was identified for WB30-d. The range of BHPs for WB30-d was 19.23-25.34 HP which was smaller than the power of their fitted engines. The WB30-d should fitted with main engines of 20 HP.

The range of BHP of the WB120 was 34.35-50.89 HP. The fitted engine power of this transportation boats was much greater than the requirements. Main engines of 40-50 HP are sufficient for this type of boats. The boats are operated mainly for transporting fishers from the port to the liftnet locations, about 4 hours per night and consumes little fuel. The use of such engines of excessive power was due to the conversion of available truck diesel engines to marine engines. A normal marine engine has low engine speed but large torque while a truck diesel engine has high speed but small torque. It means that the truck diesel engine can generate same thrust as the marine engine [8].

3.3 Fuel carried on-board and theoretical requirements

In the one-day fishing scheme, the operational duration of the main engine is the sum of travel duration from departure at the port, navigation to fishing area, gear deployment, hauling the catch, and leaving the fishing area to the port. In general, the fuel carried on-board are commonly larger than the theoretical fuel requirements (Figure 1), the exception was identified for WB120. Fishing boats of WB40-or and FRP15 carried extra fuel as much as around 100% more while WB40, WB30-d, and FRP5.5 were about 50-70% more than the requirements. In contrast to the other 5 boat types, the WB120 carried fuel less than the requirement.
Fig. 1. Theoretical fuel requirements and the fuel carried on-board by types of fishing boat

WB120 is mainly used for transporting fishers and carrying the catch of the liftnets. Its operation is regular and mostly predictable, traveling from fishing port to certain locations onward and backward. The capacity of fuel container is 150-200 litres. The fuel carried on-board is hardly used up, then the boat refill is less than the theoretical fuel required. Therefore, even the reported refilled fuel carried on-board was less than the requirements, the fuel was not insufficient for the boat operation. This findings indicate that the reported amount of fuel for WB120 is still acceptable.

Based on the description above, it can be said that the fishers can determine the amount of fuel carried onboard well. Extra fuel was prepared to avoid fuel shortages in fishing operations.

4 Conclusion

The fishing fleets at Palabuhanratu Fishing Port consist of diverse type of fishing gear but can be distinguished into 6 groups of fishing boats, namely (1) 40 HP wooden boats (WB40), (2) 40 HP outrigger wooden-boat (WB40-Or), (3) 15 HP fiberglass reinforced plastic (FRP) boats (FRP15), (4) 5.5 HP FRP boats (FRP5.5), (5) 30 HP diesel inboard-motorised wooden boats (WB30-d), and (6) 100-120 PS inboard-motorised wooden boat (WB120).

The power of the current main engine was generally higher that the requirements except FRP5.5. The main engines of two types of fishing boats (i.e., WB40 and FRP5.5) can be considered appropriate. Meanwhile, the amount of fuel carried-onboard was generally greater that the requirements, except for the WB120.

Recommendation: The current research calculated the theoretical requirements of engine power based solely on principle dimension of fishing boats. Further research needs to be carried out to estimate the power requirements based on the overall load.
carried by the fishing boats. Since fuel consumption is determined by the age of the main engines, the effects of the age of main engines on the propulsion (i.e. thrust force) can be investigated.

Issues on the low efficiency in the fishing operation due to some increase in fuel price in the future can be anticipated by replacing inappropriate main engines with sufficient power. This can be done when the main engines reach their operational lifetime.

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