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EFFICIENCY AND CAPACITY OF TRAWLERS IN WEST COAST PENINSULAR MALAYSIA

(*Kecekapan dan Kapasiti Pukat Tunda di Pantai Barat Semenanjung Malaysia*)

MUHAMMAD DANIAL ABDULLAH*, WAN ROSMANIRA ISMAIL,
AISHAH NAJIHAH ALIAS & NOR HAMIZAH MISWAN

ABSTRACT

This study discusses the efficiency, capacity and capacity utilization of fish trawlers of various zones in the west coast of Peninsular Malaysia in 2011. Data for this study were obtained from the Department of Fisheries Malaysia. An input-oriented Data Envelopment Analysis (DEA) model assuming the constant return to scale (CRS) technology was used to measure the technical efficiency and an output-oriented DEA model based on variable returns to scale (VRS) was implemented for the efficiency of capacity and capacity utilization. The study found that nearly 80% of trawlers fishing on the West Coast of Peninsular Malaysia is efficient and have an average 0.90 capacity utilization. Only fish trawlers in Perlis C2 Zone, B Zone and C Zone in Kedah were inefficient and has excess capacity to be reduced respectively by 58%, 29% and 38%. Overall current capacity can be increased by 6.14% if the excess capacity have been overcome.

Keywords: efficiency; capacity; capacity utilization; trawlers

ABSTRAK

Kajian ini membincangkan kecekapan, kapasiti dan penggunaan kapasiti pukat tunda ikan pelbagai zon di pantai barat Semenanjung Malaysia pada tahun 2011. Data bagi kajian ini diperoleh daripada Jabatan Perikanan Malaysia. Model Analisis Penyampulan Data (APD) berorientasikan input dengan mengandaikan pulangan malar mengikut skala (PMS) digunakan untuk mengukur kecekapan teknikal dan model APD berorientasikan output berdasarkan pulangan berubah mengikut skala (PBS) telah dilaksanakan untuk memperoleh kecekapan kapasiti dan penggunaan kapasiti. Kajian mendapati hampir 80% pukat tunda menangkap ikan di Pantai Barat Semenanjung Malaysia adalah cekap dan mempunyai purata penggunaan kapasiti 0.90. Hanya pukat tunda ikan di Zon C2 Perlis, Zon B dan Zon C di Kedah yang tidak cekap dan mempunyai lebihan kapasiti untuk dikurangkan masing-masing sebanyak 58%, 29% dan 38%. Kapasiti arus keseluruhan boleh ditingkatkan sebanyak 6.14% sekiranya lebihan kapasiti telah diatasi.

Kata kunci: kecekapan; kapasiti; penggunaan kapasiti; pukat tunda

1. Introduction

Although the marine capture fisheries sub-sector is able to attract a large number of investments and provide many employment opportunities as well as provide a decent income, it is found that the development of this sub-sector also faces several problems that can curb the progress design of the agricultural sector formed by the Government of Malaysia. Among the major problems faced are:

i. Fisheries resources, especially demersal fish resources, are experiencing a precipitous decline. A study made by Department of Fisheries (DOF) Malaysia in 1997-1998 found that demersal resources have been overexploited. This study area which covers the country's waters from 12 nautical miles to the Exclusive Economic Zone (EEZ) line has shown the potential budget of demersal fish resources to be at the level of 55,600 - 72,000 metric tonnes. Landings of 317,990 metric tonnes (demersal fish and trash fish) in 2007 indicate this resource has been exploited well beyond the optima stage for steady exploitation (Ahmad *et al.* 2003).

ii. According to the Traditional Fishermen's Income Study in 2008, there were as many as 62,534 local fishermen across Malaysia. Of this number, there are still poor fishermen, for example in East Malaysia, 31.1% of fishermen are very poor, 27.7% of fishermen are poor and 10.5% of fishermen are at risk of becoming poor (Lembaga Kemajuan Ikan Malaysia 2009).

iii. Malaysia is experiencing a seafood deficit issue where there is a gap between consumption and production which causes Malaysia to still import fish from neighbouring countries such as Thailand, China and Indonesia to accommodate domestic demand. This also causes a deficit to the country's balance of trade (Samsuddin 2020).

iv. There is a conflict between commercial fishers of tug trawlers and traditional fishers (Zone A) who operate simple fishing gears such as drift trawlers, traps, fishing rods, longlines and so on operating in the water area near the coast. This is because drift trawl vessels often invade the fishing grounds of traditional fishermen, causing fish depletion and contributing to the destruction of traditional fishermen's fishing gear. For example, during 2011 in Penang, as many as five fishing trawlers were arrested for wrongfully encroaching on Area A under Section 13 of the 1985 Fisheries Act (Dermawan 2023).

Apart from the factors of environmental changes caused by pollution, climate change, overexploitation and many more, among the well-known causes of this problem is due to the overexploitation of fisheries resources. This happens because of the usage of destructive fishing gears such as bombs, apollo trawls, purse seines and trawlers. These will give threats to cultural environments and both fish populations, and their habitats and it should not be a negotiated settlement between human activities and the environment; rather, it should be prohibited (Jarvis 2022). However, the government has previously taken steps to address this issue by enacting the Fisheries Act (1985), which prohibits the use of fishing gears such as bombs, cyanide, two-bot fish tug trawlers, and trawlers. Nevertheless, the usage of trawlers is still allowed because of the contribution is undeniable in this fishing industry. Based on report from Department of Fisheries Malaysia, (DOF) (Jabatan Perikanan Malaysia 2011), trawlers give huge contribution to the landings marine fish by fishing gear which is 48.19%. But at the same time, DOF policy is continuing to reduce the number of trawlers by years (Jabatan Perikanan Malaysia 2007). Therefore, measurements of the technical capabilities and capacities of trawlers need to be made to realize the best mechanism to reduce its impact on the dwindling fisheries resources and at the same time offset its contribution. The main objective of this study was to assess the efficiency and capacity of the Zones B, C and C2 trawlers. Specifically, this study was conducted to determine the technical efficiency of trawlers by zone and country on the west coast of Peninsular Malaysia, measuring the capacity and utilization of the fishing vessel capacity of trawlers for each zone in the west coast states of Peninsular Malaysia.

The scope of this study is to focus on trawler vessel Zones B, C and C2 on the West Coast of Peninsular Malaysia which includes the states of Perlis, Kedah, Penang, Perak, Selangor and West Johor. Negeri Sembilan and Melaka are not included in the scope of this study because they do not have trawlers. In Malaysia's fishing vessel delineation system, trawlers are not allowed to operate in Zone A because it reserved only for traditional fishers. While, the fishing vessel delineation system for the west coast and east coast of Peninsular Malaysia are as shown in Figure 1.

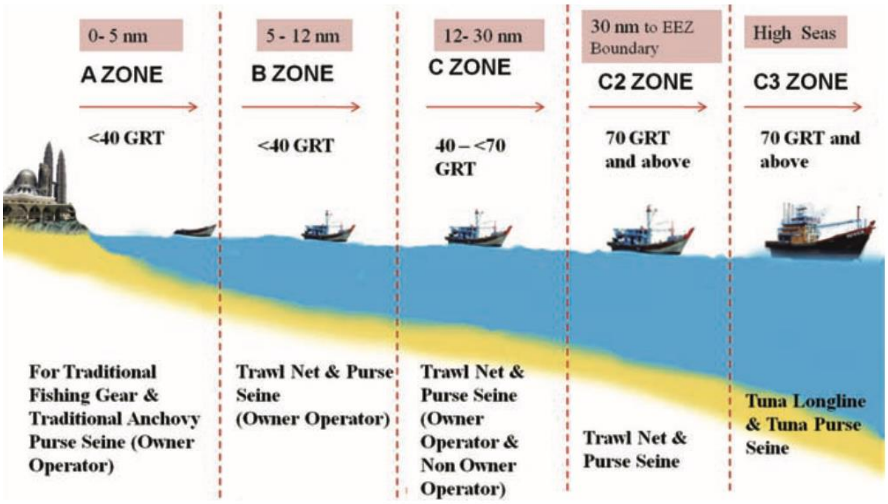

Figure 1: The fisheries zoning system in Malaysia (Shaupi *et al.* 2011)

2. Methodology

Data Envelopment Analysis (DEA) is a non-parametric linear programming method that estimates a production boundary function for a set of decision-making units (DMU). This method was originally developed to assess technical efficiency by Charnes, Cooper and Rhodes (CCR) in 1978 and followed by Banker, Charnes and Cooper (BCC) in 1984 based on the theoretical concept of efficiency proposed by Farrel in 1957 (Pascoe & Tingley 2006). In this study, the DMU used are zonal fishing trawl vessels in the West Coast states of Peninsular Malaysia. Comparisons between DMU will be made with reference to the most efficient DMU. DEA methods are divided into two orientations, namely input or output orientation and depend on the objective of the study being carried out. For input-orientated DEA methods, input levels will be reduced as much as possible but the output target is still the same. In other words, input minimisation will be done without impacting the output target. Whereas the output oriented DEA method emphasizes increasing output production at the maximum level while inputs remain unchanged.

2.1. *Technical efficiency in fisheries sector*

Technical efficiency in marine capture fisheries is a measure of the ability of a fishing vessel to produce the maximum amount of fish catch through the use of given inputs and production technology (Aigner *et al.* 1977). Generally, a firm is technically efficient if it produces output at a higher rate than other firms using the same level of inputs (Youtopoulos & Lau 1973). Farrell (1957) has also identified two types of efficiency, namely technical efficiency which assesses the ability of labour to obtain maximum output from the given inputs and the scale efficiency of input collection to produce the targeted output. Fare *et al.* (2008) also defined fisheries technical efficiency as the degree to which a production unit uses inputs (e.g. number of days and number of crew) to produce outputs (e.g. fish catch).

Measuring technical efficiency can provide information on whether there is development potential in the commercial fishing sector (Fousekis & Klonaris 2003). By measuring the technical efficiency of fishing vessels according to various load classes or vessel lengths, the assessor will also be able to make comparisons and draw conclusions whether the load classes or vessel lengths has an influence on the efficiency.

Although many technical efficiency measurements are using Stochastic Frontier Analysis (SFA), technical efficiency measurements of fishing vessels have also been shown to be successful using DEA (Pascoe & Tingley 2006). For example, Rais *et al.* (2019) used DEA to measure the efficiency level of fisheries production in Malaysia. And research from Suhaimi *et al.* (2011) assessed the technical proficiency of Kuala Terengganu coastal fisheries through a research study that involved 100 fishermen for fishing activities from January to December 2006 and used DEA methods to analyse technical proficiency. The results of the study found that there was a lack of technical adequacy for the catch equipment used by fishermen in Kuala Terengganu.

Thean *et al.* (2012) also examined the influence of technology in the issue of fishery efficiency using tug trawl equipment operating in Penang using DEA and SFA through a study of 86 tug trawl vessels. The results of the study found that there is an adequacy issue in the fisheries sector using tug trawlers in Penang.

Esmaeili and Omrani (2007) have used DEA to assess the technical, designation and economic efficiency of fishermen in Hamoun lake, Iran. The study found that fishermen who attended fisheries development courses and had no problems were more efficient. Oliviera *et al.* (2009) also studied the technical and economic skills of scallop tug trawlers in southern Portugal. The results of the study found that the quantity of landings was below the level of efficiency.

Kirkley and Squires (2003) also assessed the technical proficiency of fish trawlers in Peninsular Malaysia and found that almost all fish trawlers are proficient. For the purpose of supervising the fishing business in the countries of the European Union (EU), a joint study project by EU countries to measure the sprinkling of the efficiency in the sector of marine capture fisheries of EU countries has been made and took approximately three years to be done which from 2000 to 2003 (Tingley *et al.* 2003).

The chosen DEA model is named the input-oriented Charnes, Cooper and Rhodes (CCR) model shown in Eq. (1). This model is based on the constant return to scale (CRS) technology assumption where an increase in the production resources results in a proportional increase in the output. Assuming that there are n DMUs, 0 is the DMU being evaluated, the j^{th} DMUs produce m outputs by using s inputs and θ_0 represents the efficiency score of DMU_0. x_{ik} is the actual value of input i used by DMU_k and y_{jk} is the actual value of output j produced by DMU_k. Meanwhile, u and v are the weights attached to inputs and outputs. Mathematically, the relative efficiency of the k^{th} DMU is given by:

$$\begin{aligned}
&Max\ \theta_0 = \sum_{j=1}^{m} u_j y_{j0} \\
&\text{subject to} \\
&\sum_{i=1}^{s} v_i x_{i0} = 1 \\
&\sum_{j=1}^{m} u_j y_{jk} - \sum_{i=1}^{s} v_i x_{ik} \leq 0 \\
&v_i \geq 0, \qquad u_j \geq 0
\end{aligned} \tag{1}$$

2.2. *Capacity measurement and capacity utilisation*

Capacity and capacity utilisation (CU) have become an important focus in fisheries management. In 1995, articles 6 and 7 in the Code of Practice for Responsible Fisheries (CPRF) by Food and Agriculture Organization (FAO) had emphasised the issue of overcapacity and urged member states to take action to reduce overcapacity in marine capture fisheries (Kirkley & Squires 2003). FAO has also provided an International Action Plan for the Management of Fisheries Capacities (FAO 1999). As a continuation of the plan, in 2000 FAO has proposed the DEA method as a better approach to be adopted in the measurement of fisheries catch capacity. Subsequently, FAO has also provided several technical papers on fisheries capacity measurement as guidance to member countries (Pascoe & Gréboval 2003).

FAO (2000), Kirkley and Squires (2003) and Gréboval (2001) have defined fishery catch capacity as the maximum number of fish landings that can be produced by fully operational fishing vessels using existing technology and fish resources. In short, fishery capacity is the ability of a vessel or fleet to catch fish. Vestergaard *et al.* (2003) also defined fishing capacity as the maximum amount of fish catch that a vessel can produce if inputs are fully utilised, and given a biodynamic, fixed input, age structure of the fish stock and current technological conditions. From a more practical and broad economic perspective, Färe *et al*. (1994) define capacity as the level of output that can be produced by a manufacturer who clearly knows the profit or goal that can be achieved through customised or predetermined operating procedures.

Johansen (1968) also defines capacity as the maximum potential output that can be produced taking into account no constraints from given changing factors. This definition is an alternative definition that is increasingly receiving attention from reviewers in measuring fisheries harvesting capacity. This definition is seen as an engineering technology definition or more of an economic technology definition (Färe *et al*. 1994). Furthermore, Färe *et al*. (1994) have used DEA to measure and assess the capacity and capacity utilisation of a scallop tug trawl fishery vessel using limited data. According to him, DEA provides a rather simple framework for measuring fishery capacity because it allows maximum output to be measured only through fixed factors or limited data. He also states that DEA is a non-parametric technique that does not require a functional relationship between inputs and outputs and parameterised budgets against statistical distributions.

Dupont *et al*. (2002), Vestergaard *et al.* (2003) and Tingley *et al.* (2003) also used DEA to estimate capacities and analysed different types of fishing vessels such as Nova Scotia mobile, Danish drift trawlers and UK shipping vessels operating in the English Channel. At a macro level in Malaysia, there are no studies that focus on fisheries capacity budgeting using the DEA method approach. However, in 2003 the FAO had circulated a technical paper on fisheries, numbered 433/2, which provided guidance on various methods of estimating fisheries capacity that could be used by member countries. In the technical paper, FAO has listed several techniques for measuring capacity and capacity utilisation. Among them are Rapid appraisal techniques; Surveys and expert opinion; Peak-to-peak analysis; SFA and DEA.

The indicated DEA model in this situation is the output-oriented Banker, Charnes and Cooper (BCC) model shown in Eq. (2). This model is based on the variable return to scale (VRS) technology assumption that production technology may exhibit increasing, constant and decreasing returns to scale. Assuming that there are n DMUs, 0 is the DMU being evaluated, the j^{th} DMUs produce m outputs by using s inputs and θ_0 represents the efficiency score of DMU_0 and μ_0 represents the scale factor. x_{ik} is the actual value of input i used by DMU_k and y_{jk} is the actual value of output j produced by DMU_k. Meanwhile, u and v are the weights attached to inputs and outputs. Mathematically, the relative efficiency of the k^{th} DMU is given by:

$$Min\ \theta_0 = \sum_{i=1}^{s} v_i x_{i0} + \mu_0$$
subject to
$$\sum_{j=1}^{m} u_j y_{j0} = 1 \qquad (2)$$
$$\sum_{i=1}^{s} v_i x_{ik} - \sum_{j=1}^{m} u_j y_{jk} + \mu_0 \geq 0$$
$$v_i \geq 0, \qquad u_j \geq 0, \qquad \mu_0\ free\ in\ sign$$

2.3. *Determination of inputs and outputs*

The paper by Sangün *et al.* (2018) and Oliviera *et al*. (2009) used quantity landing as the output of the study. Similarly approach done by Hoff (2006) and Squires and Reid (2004), the output used was fish catches by species. furthermore, Ashraf-Roszopor *et al.* (2019) and Thean *et al.* (2011), also used kilograms of fish per trip as the output, while the inputs used in this study are the number of workers, engine horsepower, vessel load, number of days per fishing trip and number of litres of diesel per fishing trip. In this study the determination of output is used according to the classification that has been established by DOF and Oliviera *et al*. (2009) that is the number of fish landings in metric tonnes. Meanwhile, inputs of the study have been determined based on the classification by DOF, Thean *et al.* (2011) and Kirkley and Squires (1999), that are the number of fishermen, number of days and number of fish trawl tugboat vessels of all zones. Kirkley and Squires (1999) also stated that the number of fishing days symbolises the use of capital, energy, labour and materials of a vessel and can also be used as output.

For budgeting the capacity of a fishery, data of fish stock or fish density need to be considered (FAO 2000). However, the latest data of fish stock of demersal fish in west coast could not be obtain since the last survey made by DOF was around 1997-1998. Hence, the alternative way did by Kim *et al*. (2012), Haggarty and King (2006), Pascoe *et al*. (2004), which they used catch per unit of effort, CPUE as symbolizing the biodynamics of fish stocks affecting the fish landings. This CPUE refers to the total catch per effort expended to catch fish using the existing assets or energy (i.e., vessels, fishing period, engine size etc.). it is also referred to the productivity level of a vessel with the use of one output and input as follows:

$$\text{CPUE} = \frac{\text{Total Fish Catch}}{\text{Number of Vessels}}$$

$$\text{CPUE} = \frac{\text{Total Fish Catch}}{\text{Number of Fishing Hours}}$$

DEA analysis according to Golany and Roll (1989) requires the number of DMU and the use of outputs and inputs that fulfil the following conditions:

DMU number > 2 (Output + Input)

However, Bowlin (1998) also suggested, for more informed decision, DMU number must fulfil the following conditions:

DMU number > 3 (Output + Input)

For this study, 13 DMUs with four inputs and one output were used. Thus this study complies with the requirements set by Golany and Roll (1989) in obtaining more meaningful and appropriate decisions to measure the technical efficiency and capacity of the tugboat trawl fishery.

3. Results

Descriptive analysis is the basic analysis that needs to be done on the data for every study conducted. Descriptive analysis provides an overview of the data used and through this analysis, extreme or incongruent data values can be detected. The descriptive analysis schedule in Table 1 shows no inconsistent values between the minimum and maximum values. This indicates the data collected can be used to run more in-depth analyses.

Table 1: Descriptive analysis of Zone B fish tug trawls on the West Coast of Peninsular Malaysia in 2011

State	Zone	Landing	Number of Vessels	Days	CPUE
Perlis	B	13642	121	3703	0.058
	C	38530	66	6035	0.160
	C2	2170	14	745	0.304
Kedah	B	21108	238	4428	0.056
	C	17845	180	5655	0.059
	C2	3818	10	372	0.290
Penang	B	22172	84	1040	0.124
Perak	B	62288	866	15025	0.040
	C	70916	354	12704	0.057
	C2	25773	80	12101	0.107
Selangor	B	71107	586	10875	0.089
	C	11591	103	4491	0.074
West Johor	B	6487	125	507	0.038

In general, Data Envelopment Analysis (DEA) is a linear programming method used to measure the efficiency of decision-making units (DMU) characterised by similar inputs and outputs but possibly different in terms of quantity. In this study, the DMU used are zonal fishing trawl vessels in the West Coast states of Peninsular Malaysia. By using this input-oriented DEA method assuming variable returns to scale (VRS) model, the result of efficiency of fishing trawlers in all zones of various loads by state are shown as in Figure 2.

Figure 2: Technical efficiency of trawlers by zone and country

Based on the Figure 2, almost all fish trawl vessels in the West Coast of Peninsular Malaysia (i.e. 80%) are efficient except for Zone C2 fish trawl vessels in Perlis and Zone B and Zone C fish trawl vessels in Kedah. This analysis can also identify the best practice unit through reference frequency estimation as shown in Table 2.

Table 2: DMU of trawlers by zone and country

State	Zone	Referral Frequency
Perlis	B	0
	C	0
	C2	0
Kedah	B	0
	C	0
	C2	1
Penang	B	0
Perak	B	1
	C	2
	C2	1
Selangor	B	0
	C	0
West Johor	B	3

According to the referral frequency in Table 2, the trawlers of Zone B in West Johor district have the highest referral frequency by 3 times, and this shows that West Johor is the 'best practice unit' which can be a benchmark to the other DMU. An input-oriented DEA model that assuming variable returns to scale (VRS) can suggest a reduction in inputs for trawlers vessels that are not efficient. Which the inputs used in this study are number of vessels, number of fishers and number of fishing days as well as catch per unit effort (CPUE). Figure 3 shows the summary of the vessel reduction that need to be made by inefficient DMU for fishing trawler vessels in Zones B, C and C2, based on the analysis using DEA method of the input oriented VRS model.

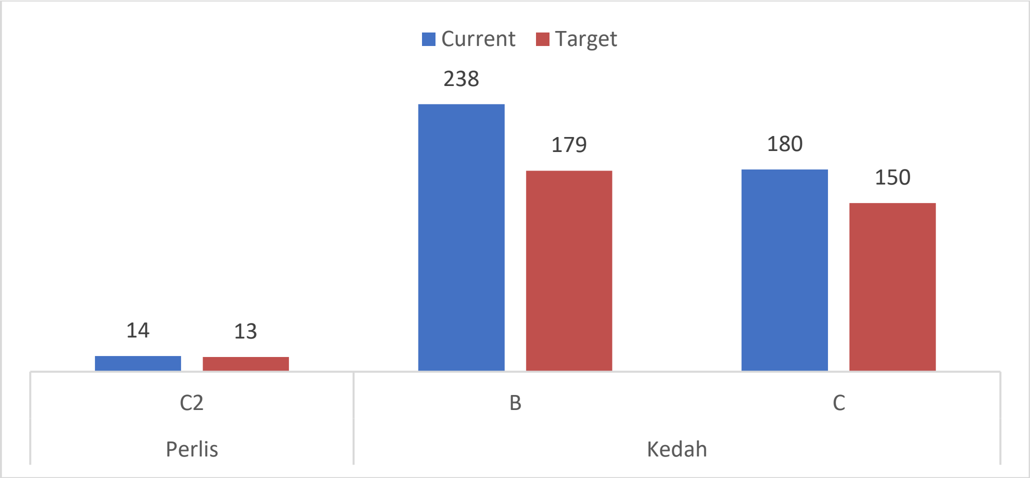

Figure 3: Targeted reduction of inadequate fishing trawler

For fishing trawler in Zone C2 in Perlis, one vessel needs to be reduced from actual number. While, in Zone B at Kedah, fishing trawler need to be reduced by 59 vessels, which is almost 25% of the existing number of Zone B trawler. Meanwhile, in Zone C at the same state, the fishing trawler need to be reduced by 30 vessels, which is 16% from the existing trawler. The proposed vessel reduction mechanism is through the Malaysian Fisheries Department's Exit Plan program.

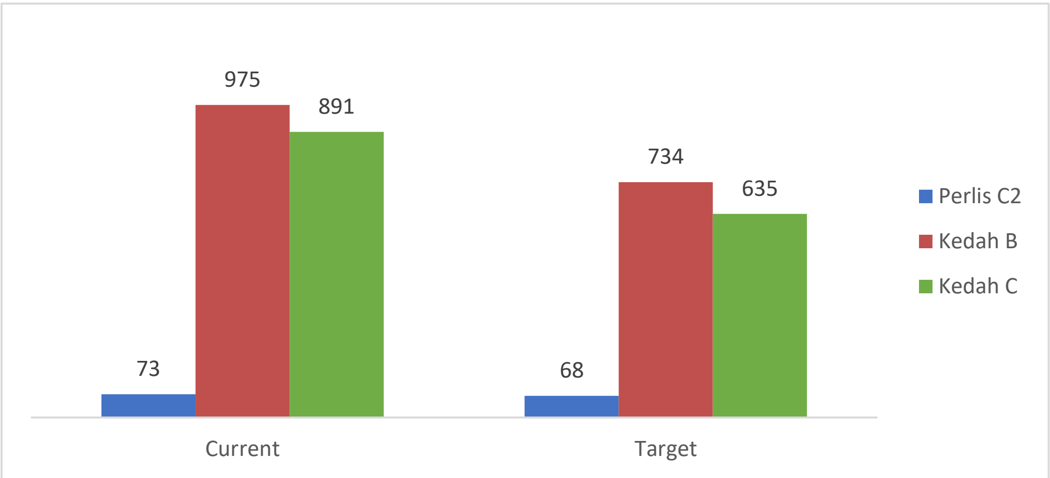

Figure 4: Targeted reduction of inadequate trawlers

For trawlers in Zone C2 in Perlis, five fishermen need to be reduced. While for trawlers in Zone B, 241 fishermen need to be reduced, which is almost 25% of the existing number of Zone B trawlers. Meanwhile, Zone C trawlers in Kedah need to be reduced by 256 fishermen, which is 16% from the existing trawlers. The proposed fishing reduction mechanism is through the Exit Plan program and the Azam Tani Program, Department of Fisheries Malaysia.

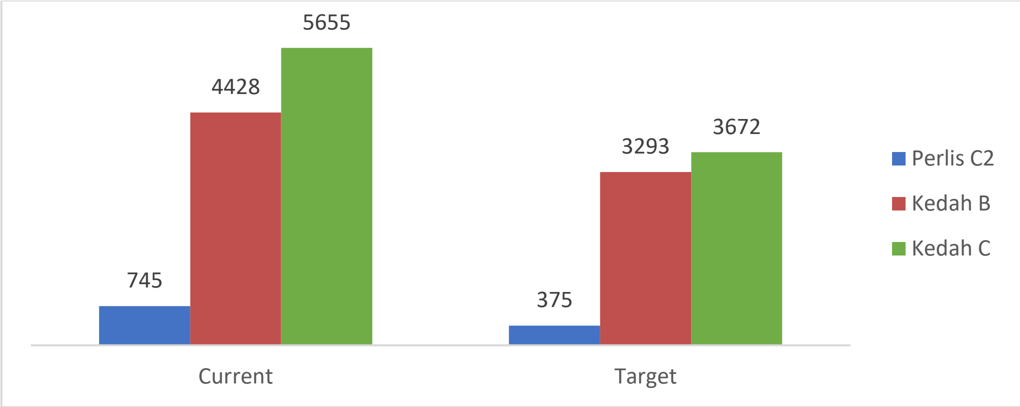

Figure 5: Targeted reduction in the number of days fishing for trawlers who are not well-equipped

Referring to Figure 5, reduction in the number of fishing days of a fishing trawler can be reduced if the vessel uses modern electronic equipment that helps save time searching and catching fish such as radar, echo sounder, GPS etc. The target for reducing the number of fishing days of inefficient Zone C2 trawlers in Perlis is 370 days. While the number of fishing days for Zone B trawlers in Kedah needs to be reduced by 1135 days, which is almost 25% from the existing number of fishing days to achieve technical efficiency. The number of fishing days for Zone C fish tug trawlers in Kedah needs to be reduced by 1583 days, which is 16% of the current number of fishing days. In addition, DOF can used this information to promote the use of additional electronic equipment especially to the trawler operators in Kedah and Perlis. These promotional activities can be done through organizing courses or seminars to the trawler operator.

The CPUE calculation is the ratio of total fish catch to total hours of fishing. Although the DEA analysis of the input oriented VRS model suggests a reduction in CPUE to overcome the inefficiency of fishing trawlers in Zone C2 in Perlis, Zone B and Zone C in Kedah, but in this study, CPUE represents the fish stock or density of fish in the operation area of trawlers. Therefore, the proposed reduction of CPUE cannot be done on the contrary.

For the measurement of capacity using the an output-orientated DEA model, assuming variable returns to scale (VRS), the analysis results obtained are as shown in Figure 6.

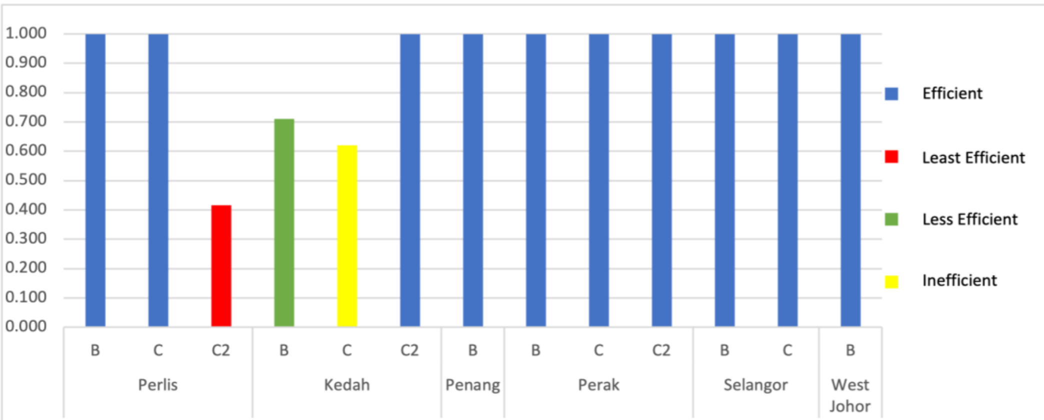

Figure 6: Vessel capacity usage of fish tug trawlers by zone and state on the West Coast of Peninsular Malaysia

Based on Figure 6, the value of capacity utilization less than 1 indicates that there is excess capacity in the trawlers of Zone C2 in Perlis, Zone B and Zone C2 in Kedah. This conclusion is made on the assumption that all trawlers on the West Coast of Peninsular Malaysia operate by fully utilizing the inputs that have been given. Hence, overall 80% of fishing trawlers in the West Coast states do not have excess capacity utilization.

Table 3 also shows the potential capacity, i.e., the maximum catch of fish that can be produced by trawlers in Zone C2 in Perlis, Zone B and Zone C2 in Kedah, if the excess capacity can be deducted.

Table 3: Potential capacity of trawlers of Zone C2 Perlis, Zones B and C in Kedah

Country	Zone	Current Capacity (TM)	Potential Capacities (TM)	Per cent Capacities Can Be Improved (%)
Perlis	C2	2170	5213	140
Kedah	B	21108	29738	41
	C	17845	28755	61

4. Conclusions

To reduce the number of fishing trawlers, one of the platforms that can be used by the Department of Fisheries Malaysia, DOF is through the Exit Plan Programme. Currently, DOF has disposed as many as 117 fishing trawlers in Kedah through this programme. The reduction of fishing trawlers through such a programme will reduce the pressure on fisheries resources, especially in Zone B. This will allow fish stocks in the area to recover and increase. The productivity of fish trawlers will also increase by reducing inputs such as the number of vessels if fish stocks have declined (Islam *et al.* 2011).

In addition, reducing the use of fishing trawlers will also ease the conflict between trawlers and traditional fishermen in Zone A. This conflict occurs due to the activity of trawlers invasion into Zone A which not only affects the catch of traditional fishermen but also causes damage to their fishing equipment such as drift trawls or *bubu*. Indirectly the CPUE of Zone A fishermen will also increase if this invasion can be reduced or fully being restricted. The reduced of fish trawlers can also be used as an artificial reef which will be able to promote fish breeding grounds. The use of fishing trawlers as artificial reef will also be able to save a large expense by the government to build artificial reef.

Although the Exit Plan programme may reduce the number of fishermen or fishing trawlers, it is also recommended that various fisheries product downstream and upstream activity programmes be introduced to them. Through these programmes, they are not only given encouragement and support to dive into the field of producing fish-based food products but also involve in other fields such as aquaculture, farming, or agriculture.

The number of fishing days of tugboat trawl vessels can be reduced through the introduction of various latest modern fishing equipment technologies. The latest electronic fishing equipment such as radar, echo sounder, Global Positioning System (GPS) and others, can help trawler skippers to save time looking for fishing locations that have the potential to get a large number of fish caught. For example, currently DOF has introduced the delivery systems and development support service, Automatic Identification System (AIS) (Jabatan Perikanan

Malaysia 2015). This system is a new technology that has been introduced by DOF to fishermen in this country for fishing operations. AIS provides benefits to fishermen as follows:

i. Assist in vessel navigation throughout the voyage such as vessel positioning (latitude and longitude), vessel speed, wave conditions, course bearing and distance from destination.
ii. Vessel safety when anxiety prevails with the convenience of an emergency/panic button.
iii. Determination of international border areas and fishing zones. Alerts are displayed when orientating these areas.
iv. Recording fish catch information.
v. Two-way communication through message transmission.
vi. Marking of popular/strategic fishing locations.

The technical efficiency of vessels can be improved if the use of new technology is introduced to fishermen who are identified as inefficient. Therefore, DOF is also suggested to introduce new equipment in AIS to attract fishermen or trawlers more actively through appropriate programs.

In the measurement of the capacity and utilization of fishing trawl vessels capacity, DOF is advised to examine the need to introduce the Total Allowable Catch (TAC) regulations. In EU countries, TAC is one of the mechanisms used to manage fisheries resources. Currently in Malaysia, a fishing trawler can catch as much fish as they want, without any limit being introduced. Only a minimum amount of fish catch has been introduced to ensure that the diesel or petrol subsidies given are not misused for activities other than fishing. The requirement can prevent fishermen or fishing vessel operators from misusing the fuel subsidy that has been given by the government. The requirement is made because, there were many cases of selling subsidized fuel by fishermen and even worse, there were fishing vessel operators who sold subsidized oil in neighbouring countries such as Thailand where the price was more expensive.

The setting of the minimum fish catch, and the absence of TAC regulations are very detrimental to the country. This is because fisheries resources will be exposed to the greedy attitude of humans who are only concerned with profit without knowing the importance for the sustainability of fisheries resources in the long term. In EU countries, fishing vessel operators that are not actively operating in fishing at sea can sell their TAC to active operators. The results of the study on the measurement of the capacity and utilization of the capacity of the trawlers vessel will enable DOF to determine the maximum number of fish that can be caught by considering the fish stock and existing technology.

References

Ahmad A.T., Hong T.G. & Yasin A.H. 2003. Overview of the national fisheries situation with emphasis on the demersal fisheries off the West Coast Peninsular Malaysia. *WorldFish Centre Conference Proceedings*, pp. 833-884.

Aigner D., Lovell C.A.K. & Schmidt P. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* **6**(1): 21-37.

Ashraf-Roszopor M., Dayang-Affizzah A.M., Abdullah A.M., Latif I.L. & Nor Afiza A.B. 2019. Technical efficiency analysis of Terubok fisheries in Malaysia. *Journal of Public Administration and Governance* **8**(4): 311–327.

Banker R.D., Charnes A. & Cooper W.W. 1984. Some models for estimating technical and scale inefficiency in DEA. *Management Sciences* **30**(9): 1078-1092.

Bowlin W.F. 1998. Measuring performance: An introduction to Data Envelopment Analysis (DEA). *The Journal of Cost Analysis* **15**(2): 3-27.

Charnes A., Coopers W.W. & Rhodes E. 1978. Measuring efficiency of decision making units. *Journal of Operation Research Society* **2**(6): 429-444.

Dermawan A. 2023. MMEA detains 5 men on suspicion of illegal fishing off Pulau Kendi. https://www.nst.com.my/news/crime-courts/2023/02/884301/mmea-detains-5-men-suspicion-illegal-fishing-pulau-kendi (5 March 2023).

Dupont D.P., Grafton R.Q., Kirkley J. & Squires D. 2002. Capacity utilisation measures and excess capacity in multi-product privatised fisheries. *Resource Energy Economics* **24**(3): 193-210.

Esmaeili A. & Omrani M. 2007. Efficiency Analysis of fishery in Hamoon lake: Using DEA approach. *Journal of Applied Sciences* **7**(19): 2856-2860.

FAO 1999. Report of the Technical Working Group on the Management of Fishing Capacity. FAO Fisheries Report No. 586. Rome, Italy. https://www.fao.org/3/x0488e/x0488e00.htm

FAO. 2000. Report of the Technical Consultation on the Measurement of Fishing Capacity. FAO Fisheries Report No. 615. Rome, Italy. https://www.fao.org/3/x4874e/x4874e.pdf

Färe R., Grosskoff S., Norris M. & Zhang Z. 1994. Productivity growth, technical progress and efficiency change in industrialised countries. *The American Economic Review* **84**(1): 66-83.

Fare R., Grosskopf S. & Lovell C.A.K. 2008. *Production Frontier*. Cambridge: Cambridge University Press.

Farrell M.J. 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society* **120**(3): 253-290.

Fousekis P. & Klonaris S. 2003. Technical efficiency determinants for fisheries: a study of trammel netters in Greece. *Fisheries Research* **63**(1): 85-95.

Golany B. & Roll Y. 1989. An application procedure for DEA. *Omega* **17**(3): 237-250.

Gréboval D.F. 2001. The international plan of action for the management of fishing capacity and selected issues pertaining to illegal, unreported and unregulated fishing. *FAO Fisheries Report* **666**.

Haggarty D.R. & King J.R. 2006. CPUE as an index of relative abundance for nearshore reef fishes. *Fisheries Research* **81**(1): 89-93.

Hoff A. 2006. Bootstrapping Malmquist indices for Danish seiners in the North sea and Skagerrak. *Journal of Applied Statistics* **33**(9): 891-907.

Islam G.M.N., Noh K.M. & Yew T.S. 2011. Measuring productivity in fishery sector of Peninsular Malaysia. *Fisheries Research* **108**(1): 52-57.

Jabatan Perikanan Malaysia. 2015. Pelan Strategik Pengurusan Perikanan Tangkapan Malaysia (2015-2020). Putrajaya: Jabatan Perikanan Malaysia.

Jarvis C. 2022. Trawling and the threat to underwater cultural heritage. https://oceanfdn.org/trawling-and-the-threat-to-underwater-cultural-heritage/ (5 Oktober 2023).

Johansen L. 1968. Production functions and the concept of capacity, recherches recentes sur la fonction de production, collection. *Economie Mathematique et Econometrie* **2**: 49-72.

Kim D.-H., Seo J.-N., Kim H.-S.M. & Lee K. 2012. Estimation of productivity growth, technical progress and efficiency changes in the Korean offshore fisheries. *Fish Science* **78**: 743-751.

Kirkley J.E. & Squire D. 1999. Measuring Capacity and Capacity Utilization in Fisheries. In Gréboval D (ed). *Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues*: pp 75-200. FAO Fisheries Technical Paper No 386.

Kirkley J.E. & Squires D. 2003. *Capacity and capacity utilisation in fishing industries*. VIMS Books and Book Chapters. 61. https://scholarworks.wm.edu/vimsbooks/61

Lembaga Kemajuan Ikan Malaysia. 2009. Laporan Tahunan 2009. https://www.lkim.gov.my/wp-content/uploads/2020/10/2009-Laporan-Tahunan-LKIM_opt.pdf (1 May 2023).

Suhaimi N.A.M., Hussein M.A., Latiff I. & Mohayidin G. 2011. Level of technical efficiency of inshore fisheries in Kuala Terengganu. *Economic and Technology Management Review* **6**: 83-91.

Oliviera M.M., Gaspar M.B., Paixao J.P. & Camanho A.S. 2009. Productivity change of the artisanal fishing fleet in Portugal: a Malmquist index analysis. *Fisheries Research* **95**(2–3): 189-197.

Pascoe S. & Gréboval D. 2003. Measuring Capacity in Fisheries. FAO Fisheries Technical Paper No. 445. Rome, Italy. https://www.fao.org/3/y4849e/y4849e.pdf

Pascoe S., Gréboval D., Kirkley J. & Lindebo E. 2004. Measuring And Appraising Capacity in Fisheries: Framework, Analytical Tools and Data Aggregation. FAO Fisheries Circular No. 994. Rome, Italy. https://www.fao.org/3/y5443e/y5443e.pdf

Pascoe S. & Tingley D. 2006. Economic capacity estimation in fisheries: A non-parametric ray approach. *Research On Energy Economics* **28**(2): 124-138.

Jabatan Perikanan Malaysia. 2007. Perangkaan Perikanan Tahunan 2007. https://www.dof.gov.my/en/resources/fisheries-statistics-i/ (1 May 2023).

Jabatan Perikanan Malaysia. 2011. Perangkaan Perikanan Tahunan 2011. https://www.dof.gov.my/en/resources/fisheries-statistics-i/ (1 May 2023).

Rais A.A.A., Khairi S.S.M., Zahid Z. & Ramli N.A. 2019. Efficiency of fishery production in Malaysia using data envelopment analysis. *Proceedings of the Third International Conference on Computing, Mathematics and Statistics (iCMS2017)*, pp. 325–332.

Samsuddin A. 2020. Cabaran Industri Perikanan Abad Ke-21. https://www.centre.my/post/cabaran-industri-perikanan (1 April 2023).
Sangün L., Güney O.İ. & Berk A. 2018. Economic efficiency performance of small-scale fisheries in the east mediterranean coast of Turkey. *New Medit* **17**(4): 71–80.
Shaupi M., Khalil A., Ahmad A.T., Saktian A., Rahman A. & Mohamed H. 2011. Putting a plug on increasing fishing capacity: NPOA for the management of fishing capacity in Malaysia. *Southeast Asian Fisheries Development Center* **9**(2): 86–90.
Squires D. & Reid C. 2004. Using the Malmquist index to measure changes in total factor productivity of purse-seine vessels while accounting for changes in capacity utilisation, the resource stock and the environment. SCTB17 Working Paper FTWG-5. 17th Meeting of the Standing Committee on Tuna and Billfish. NOAA Fisheries. La Jolla, California.
Thean L.G., Latif I.A. & Hussein M.A. 2011. Technical efficiency analysis for Penang trawl fishery, Malaysia: Applying DEA approach. *Australian Journal of Basic and Applied Sciences* **5**(12): 1518-1523.
Thean L.G., Latif I.A. & Hussein M.A. 2012. Does technology and other determinants effect fishing efficiency? An application of Stochastic Frontier and Data Envelopment analyses on trawl fishery. *Journal of Applied Science* **12** (1): 48-55.
Tingley D., Pascoe S. & Mardle S. 2003. Estimating capacity utilisation in multi-purpose, multi-métier fisheries. *Fisheries Research* **63**(1): 121-134.
Vestergaard N., Squires D. & Kirkley J.E. 2003. *Measures Of Capacity in A Multispecies Danish Fishery*. VIMS Books and Book Chapters. 63. https://scholarworks.wm.edu/vimsbooks/63
Youtopoulos P.A. & Lau L.J. 1973. A test of relative economic efficiency: Some further results. *The American Economic Review* **63**(1): 214-223.

Department of Mathematical Sciences
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 UKM Bangi
Selangor DE, MALAYSIA
E-mail: p118290@siswa.ukm.edu.my, *wrismail@ukm.edu.my, p125534@siswa.ukm.edu.my, norhamizah@ukm.edu.my*

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*Corresponding author