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Original article

The impact of climatic and environmental changes on the sustainable yield of the Saudi's capture fisheries

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ABSTRACT

Saudi Arabia aims to enhance the productivity of fish production and culture of consumption of fish products and increase the export of fish products through implementing the National Transformation Program. This study aimed to identify the current status of marine fish production and most critical climatic and environmental factors affecting the production of natural fisheries and estimate the maximum sustainable yield in Saudi Arabia by focusing on the primary fisheries in the Arabian Gulf and the Red Sea during the period 2000–2019. We found that the most important economic, climatic, and environmental factors affecting marine fish production in Saudi Arabia were the number of industrial fishing boats, number of fishers, and wind speed. There was a significant positive relationship between the quantity of fish production in Saudi's fisheries and the number of industrial fishing boats and fisher numbers. In contrast, there was an inverse relationship between wind speed and fish production in these fisheries. The total output elasticity was 0.10, which is less than 1, indicating that fish production in these fisheries is in the second production stage, which is called the economic production stage. In contrast, there is an opportunity to increase the production variables with diminishing returns. Schaefer's model analysis confirmed the ability to increase production in most of the study period in both the Arabian Gulf and the Red Sea with fishing production not exceeding the maximum sustainable level.

1. Introduction

Saudi Arabia has a geographical location that enables two seafronts: one in the eastern Arabian Gulf coast and the other in the west Red Sea coast, with a length of 1710 km. There are ample fish resources along these coasts, allowing Saudi Arabia to export up to 50 thousand tons per annum (National Transformation Program, 2018). Saudi Arabia aims to enhance the productivity of fish production and culture of consumption of fish products and export 100 tons of aquaculture products in 2020 through the implementation of the National Transformation Program. This national program aims to develop the fishery sector in Saudi Arabia and has a goal of exporting 600 thousand tons of fish products in 2030. Additionally, there is a 2030 National Visions target to increase individual domestic consumption of fish from 10 kg per capita in 2016 to 20 kg per capita in 2030 to reach the global consumption level (2030 Vision, 2020). Therefore, the local production level must be increased while ensuring the sustainability of fish resources. However, there is still a deficit in local production, with the amount of fish imports amounting to 210 thousand tons in 2018 (General Authority for Statistics, 2020).

Several climatic and environmental factors also affect fish production: sea-level rise, temperature fluctuations, increased heat, expansion of minimum oxygen levels, increased intensity and frequency of storms, freshwater flow and rainfall, ocean acidification, and salinity changes (Booth et al., 2011; Sumaila et al., 2011; Shelton, 2014; Wabnitz et al., 2018). Numerous studies have measured the level of impact of climate change on fish production using different approaches, such as using simulation models to identify possible scenarios for climate change (Cheung et al., 2009; Lam et al., 2012; Wabnitz et al., 2018; Suh & Pomeroy, 2020) and the potential of fishing and fish production under changing conditions (Cheung et al., 2008, 2010; Lam et al., 2012). These studies show that there is likely to be a change in global fishing

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productivity for some fish species, and there will probably be a significant decrease in future marine fish production. Additionally, there is likely to be a redistribution of global fishing, with possible increases in fish production in some areas and declines in fish production in other areas (Cheung et al., 2010; Blanchard et al., 2012; Lam et al., 2016).

The impact of climate change on the fish sector has substantial economic consequences, including the loss of fishery-related jobs and losses in returns. In the most affected regions, such as West Africa, the job losses could reach 50%, and income losses could reach 311 million dollars annually. Globally, some studies have forecasted a 35% decline in returns (Lam et al., 2012, 2016).

The Arabian Gulf has a diversity of fish and marine organism resources. However, these resources are at risk from the impacts of climate change. Saudi Arabia and the other Arab Gulf states are not isolated from the various influences of environmental factors and climatic changes in their many forms. The predicted increase in the average temperature and the sharp decrease in precipitation may be considered the most important factors affecting the region (Al-Maamary et al., 2017). The results of previous studies in this area predicted that climate change could lead to a further decline in many priority species, with the decline predicted to reach 35% in 2090 compared to the status quo level in 2010. However, the expected decline could vary in different regions of the Gulf, decreasing the rate of fish caught in the Arab Gulf regions by 26% or more in the future (Wabnitz et al., 2018).

This study aimed to identify the current status of marine fish production in the Arabian Gulf and Red Sea in Saudi Arabia during the period 2000–2019 and the most critical climate and environmental factors affecting fish production from natural fisheries and estimate the maximum sustainable yield (MSY) and fishing effort required to achieve a balance between production and fishing.

2. Material and methods

We used descriptive statistical methods and quantitative statistical analysis to analyze and explain the study's economic, climate, and environmental variables. Fishery production functions describe the relationship between harvest and fish stock and fishing effort. Harvest describes the output while fish stock and fishing effort represent the input (Conrad, 1999). However, the study uses a fishery production function that relates harvest to fishing effort and environmental variables. Harvest is regarded as the output of fishing in Saudi Arabia, which includes the Arabian Gulf and Red Sea during the period 2000–2019. Fishing effort and environment are regarded as the inputs that represent the number of traditional fishing boats (x_1), number of industrial fishing boats (x_2), number of fishers (x_3), quantity of fish landings by tons (x_4), average temperature in the Arabian Gulf and the Red Sea (x_5), and average wind speed in the Arabian Gulf and Red Sea (x_6). The study used multiple regression to explore the essential determinant factors affecting the fishery production function. The statistical relationship between the harvest (Y) as a dependent variable and the other factors are measured as independent variables through several mathematical formulas, including linear (Equ. 1), semi-log (Equ. 2), and double-log (Equ. 3), to estimate the function as following (Kotb, 2017; Alrouby and Abdul-Tawab, 2019). These forms were linearly homogenous (if a = 0 in linear):

$$Y = a + \sum_i b_i x_i \tag{1}$$

$$Y = \ln\ a + \sum_i b_i L n x_i \tag{2}$$

$$\ln\ Y = \ln\ a + \sum b_i L n x_i \tag{3}$$

Where a is the function constant, and b_i is the estimated regression coefficient. The function with the most significant result will be chosen based on the economic and statistical aspects such as the value of the determinate coefficient R^2, F-test, and the t-test for the parameters of the estimated function.

The physical production efficiency was also estimated based on the productive elasticity of the estimated productive function inputs. The production elasticity parameters for inputs EPX_i were obtained according to the following functions (Kotb, 2017):

$$Linear\ function : EPX_i = b_i / \left(\bar{Y} / \dot{x}_i\right) = b_i \frac{\dot{x}_i}{\bar{Y}} \tag{4}$$

$$EPX_i \geq 0$$

$$Log - linear\ function : EPX_i = b_i / \overline{Y} \tag{5}$$

$$EPX_i \geq 0$$

$$Double - log\ function : EPX_i = b_i \tag{6}$$

$$EPX_i > 0$$

where b_i is the estimated regression coefficient of production input, $\overline{Y}$ is the average quantity of production, and $\hat{\dot{x}}_i$ represents the average input quantity over the period.

The MSY was estimated because the Fisheries Department aims to restore balance to the fisheries by creating a balance between harvest and fishing rates. The MSY is estimated to achieve maximum exploitation of the fisheries without exposing stock to overfishing and is defined as the maximum annual production that can be obtained without harming the fish stock's ability to regenerate in the long run. Optimal fishing effort is estimated using the surplus production model (Schaefer, 1957). This model depends on the productivity of the fishing unit as a function of the fishing effort to estimate the maximum quantity of fishing based on the relationship between production and fishing effort, and the number of fishing units was estimated following Alrouby and Abdul-Tawab (2019):

$$C/E\ =\ \alpha\ +\ \beta E \tag{7}$$

where

C denotes the average catch of fish production of a specific species i *(Traditional or Industrial)*.

E denotes the average fishing effort used to catch a certain species i, in terms of the number of fishing units.

α, β are function parameters to be estimated.

Eq. (7) can be rewritten as:

$$C =\ \alpha\ E\ +\ \beta E^2 \tag{8}$$

The output curve reaches its highest point by are taking the first derivative with respect to the level of effort and let it equal to zero to find the level of effort. Therefore, the level of effort, number of boats, which gives maximum sustainable yield, is equal to:

$$E_{\max}\ = -\ \alpha\ /\ 2\ \beta \tag{9}$$

Now if we substitute E_{max} for E in Eq. (8), we can demonstrate that the maximum sustainable yield as below:

$$Maximum\ Sustainable\ Yield\ (MSY)\ = C_{\max} =\ -\ \alpha^2\ /\ 4\ \beta \tag{10}$$

The study used published data for 2000–2019 from the General Authority for Statistics, the Ministry of Environment, Water, Agriculture, and the Weather Underground website to obtain temperature and wind speed data.

2.1. Data description

The study used secondary data for variables for the period 2000–2019. Table 1 shows the summary data description of the variables. By looking at the change in the volume of fish harvested in Saudi Arabia from fisheries of the Arabian Gulf and the Red Sea during the period 2000–2019, Table 1 shows that the average fish harvest was 62.38 thousand tons, and the maximum volume of the fish harvest was 73.17 thousand tons in 2011 as a result of increasing domestic demand for fish because of high red meat and poultry prices. The volume of fish production increased at an annual rate of 1.4% during the study period.

Table 1 shows the change in the number and productivity of traditional and industrial fishing boats during the study period. The average number of traditional and industrial fishing boats in these fisheries was 10,768 and 181 boats, respectively, with an annual decrease of 0.03% and 0.6%, respectively. The maximum number of fishing boats in a year was 12,003 traditional boats in 2011 and 198 industrial boats in 2016, while the minimum number of fishing boats in a year was 8,436 traditional boats in 2000 and 162 industrial boats in 2017. Moreover, the average productivities were 5.19 tons for traditional boats and 39.27 tons for industrial boats during the study period at an annual increase of 12.9% for traditional fishing boats, while the change in industrial fishing boats was not statistically significant.

Furthermore, there was a 51.17% increase in the number of fishers from 2000 to 2018, with an increase from 20.09 thousand to 30.37 thousand fishers over this period, with an annual increase of 2.8% (Table 1). The average number of fishers during the period 2000–2019 was 27.06 thousand, with an average productivity of 2.31 tons.

For the climatic and environmental factors that might affect fish products, such as temperatures and winds in the Arabian Gulf and Red Sea fisheries, the average temperature and wind speed during the study period were 25.84 °C and 9.10 knots, respectively. The annual average temperatures were between 28.24 °C and 23.46 °C, while the wind speed was between 12 and 7.2 knots (Table 1). We observed increases in temperature by 0.3% annually and decreases in wind speed by an annual rate of 1.4% during the period of study.

The average daily fish production was 170.89 tons during the study period and ranged between 137.26 and 200.45 tons (Table 1). The daily production increased by an annual rate of 1.4%, on average, during the study period.

3. Results and discussion

3.1. Status of fish production in the catches of the Arabian Gulf and the Red Sea, Saudi Arabia

The study used Ordinary Least Square to estimate the linear, double-log, and linear-log models. The output of the regression analysis showed that the double-log model was the most representative of the relationship between fish harvest and other independent variables according to economic and statistical aspects, such as the value of the determination coefficient (R^2), F-test, and *t*-test for the estimated function parameters (Table 2).

The results of model (1) in Table 3 show the significance of the model estimated at a 0.01 significance level, with an F statistic of 13.3, and the value of the Durban-Watson test (DW) shows that the regression analysis is free from autocorrelation in the residuals. The variation in the explanatory factors explained 79.5% of the variation in the dependent variable (fish production in Saudi's fisheries) according to the determination coefficient value (R^2). The estimated model sufficiently represented the data used in the estimate according to the indicators used to measure the efficiency of the models, such as the square root of the mean squares of error randomization (RMSE), mean absolute error, mean absolute percentage error, and coefficient of inequality of methyl (U - Theil), which had acceptable values. Additionally, the model passed the Breusch-Godfrey correlation test and the Arch test for serial correlation in residues and autocorrelation in variance series values for all independent variables, which indicates that the regression analysis is free from serial correlation in residues and multicollinearity problems.

The results of the double-log in model (2) indicate the factors that could have an impact on fish production (Y), which represent the number of industrial fishing boats (X_3), the number of fishermen (X_4), and wind speed (X_6). A positive relationship was found between fish harvest, the number of industrial fishing boats, and the number of fishers, and an increase in these elements by 10% will increase fish production in these fisheries by 6% and 1.8%, respectively. However, there is a negative relationship between wind speed and fish production in these fisheries. A 10% increase in wind speed decreased Saudi fishery production by 6.8%. An increase in wind speed leads to an increase in wave height and strength, which endangers fisher lives and leads to them refraining from going out fishing until the weather is more stable. The Elasticity of total factor productivity of these variables is 0.10, that indicating the fish production in Saudi's fisheries is in the second production stage. During this stage, the marginal returns decrease and the total product is maximum. Model 2 is the best fit to represent the situation for the production of Saudi's fisheries according

Table 1
Descriptive analysis of fish production and some economic, climatic, and environmental variables of fish catches in the Arabian Gulf and the Red Sea, Saudi Arabia, during the period 2000–2019.

Variables		Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation %	Annual Growth Rate %
Fish Production (thousand tons)		50.1	73.17	62.38	7.93	11.11	1.4
Number of Boats	Traditional	8436	12,003	10,768.3	1,114.11	−0.03	10.3
	Industrial	162	198	181.2	11.44	−0. 60	6.3
Average of Productivity for boats (ton)	Traditional	3.6	6.8	5.2	0.92	12.9	17.7
	Industrial	26.6	50.3	39.3	7.24	−1.3	18.4
Fishermen (thousand)		20.1	30.4	27.2	2.87	10.61	0. 8
Wind speed (knots)		7.2	12.0	9.2	1.20	13.19	0.3
Temperature (Celsius degree)		23.5	28.2	25.8	0.93	3.60	−1.2
Average productivity of fishermen (ton)		1.8	3.0	2.3	0.27	11.69	1.0
Average daily production (ton)		137.3	200.5	170.9	18.98	11.11	1.4

Source: Calculated from:
1- Ministry of Regional Environment (2000–2019).
2- Weather Underground website (2020).

Table 2
Estimating the fish production function in the fisheries of Saudi Arabia during the period 2000–2019.

Equations									
Model (1)	Lny =	−4.8	−0.44lnx$_1$	+1.04lnx$_2$	+1.11lnx$_3$	+0.19lnx$_4$	+0.82lnx$_5$	−0.60lnx$_6$	Double-log model
	(t stat.)	(−1.2)	(−1.7)	(2.4)*	(4.5)**	(2.4)*	(1.9)	(−5.3)**	
Collinearity Statistics	[VIF]		[4.3]	[4.6]	[4.7]	[1.2]	[1.4]	[1.2]	
	Tolerance		0.23	0.22	0.21	0.85	0.71	0.82	
R^{-2} = 0.795				DW = 1.17			F = 13.3**		
Breusch-Godfrey Test: F = 3.37 Prob.F (1,12) = 0.10				ARCH Test: F = 0.449 Prob.F (6,13) = 0.83			Root Mean Squared Error = 0.046		
Mean Absolute Error = 0.036				Mean Abs. Percent Error = 0.33			Theil inequality coefficient = 0.002		
Model (2)	Lny =	4.66	+0.60lnx3	+0.18lnx4	−0.68lnx6				Double-log model
	(t stat.)	(2.9)**	(4.7)**	(2.4)*	(−5.8)**				
Collinearity Statistics	[VIF]		[1.01]	[1.09]	[1.08]				
	Tolerance		0.99	0.92	0.92				
R^{-2} = 0.743				DW = 1.24				F = 19.3**	

Source: Calculated from:
1- Ministry of Regional Environment (2000–2019).
2- Weather Underground website (2020).

Table 3
Estimates of production functions according to Schaefer's model.

Fishery	Schaefer Model	R^2	F
Arabian Gulf	Y_1 = 25.712–0.0034 E (8.26)** (−2.3)*	0.23	5.25*
Red Sea	Y_2 = 5.254–0.00028 E (14.03)** (−6.8)**	0.72	46.1**
Total	Y_3 = 10.212–0.00041 E (6.4)** (−2.85)*	0.31	8.13*

Source: Calculated from: 1- Ministry of Environment, Water, and Agriculture, miscellaneous issues for the period (2000–2019). 2- Weather Underground website (2020).

to economic and statistical aspects whereas all independent variables have a statistically significant effect on fish production.

3.2. The Gordon-Schaefer model for the capture fisheries of Saudi Arabia

The Gordon-Schaefer model (Eq. (7)) was used to determine the optimal fishing effort (E) that leads to achieving the MSY (Table 3), which is the maximum annual yield that could be obtained without disrupting the fish stock's ability to regenerate in the long term. Accordingly, the study analyzed the development of production and fishing units and their relationship in the Arabian Gulf, the Red Sea fisheries, and the total for all Saudi fisheries (Table 3). Y_1, Y_2, Y_3 in three equations in Table 3 are the average boat productivity in tons during the study period in the Arabian Gulf, Red Sea, and the total of fisheries, respectively. These equations are consistent with economic logic and are statistically significant. The results in Table 3 reveal that there is a negative relationship between the average boat productivity and the number of fishing boats. As the number of fishing boats increases the boat productivity decreases. The results of applying the Gordon-Schaefer production model to these fisheries are outlined in Table 4 as below.

3.2.1. The Arabian Gulf

The Arabian Gulf is one of the primary sources of fish production in Saudi Arabia. The Gulf's catch area is about 610 km, it comprises 35.7% of the total fishery area in Saudi Arabia, and it produced 42.04 thousand tons in 2019.

By applying the Schaefer surplus production model during the period 2000–2019, the MSY of fish production in the Arabian Gulf is estimated at 48,610.8 tons, of which the yield exceeds the average actual fish production from the Arabian Gulf (38,151 tons) during the study period by 27.4% (Table 4). This result provides an opportunity to increase production from the Arabian Gulf without harming the sustainability of marine organisms and biodiversity. By comparing the maximum yield with the actual yield during the study period, there is a decreasing gap between the actual catch and the MSY during all the years of the study period, which was between 48.6% and 6.9%. For the fishing effort that represented the number of fishing boats, the results indicated that the fishing effort that achieves the MSY was estimated as 3,781 boats. The results show that this above the average of the actual fishing boats during the study period (2,116 boats) by 78.8%. Also, there were decreases in actual fishing effort from the maximum during all the study periods, whereas the gap ranges were between 0.2% and 51.5%.

3.2.2. The Red Sea

The Red Sea is the second primary source of fish production in Saudi Arabia. The catch in the Red Sea area is about 1,100 km, representing almost 64.3% of the total area of fisheries in the country. The yield from this fishery was 24.2 thousand tons in 2019.

The surplus production model results during the period 2000–2019 indicate that the MSY of fish production in the Red Sea is estimated as 24,646.9 tons, whereas the average of actual fish production from the Red Sea was 23,995 tons during the study period. This means that the average of actual fish production was less than the MSY by 2.7%, indicating that an opportunity exists to increase

Table 4
Estimates of the gap between the actual and maximum sustainable yield and the actual and optimal fishing effort, 2000–2019.

Fishery	Actual Yield (Ton)	Maximum Sustainable Yield (Ton)	Gap (Ton)	Percent (%)	Actual Fishing Effort (boats)	Optimal Fishing Effort (boats)	Gap (boats)	Percent
Arabian Gulf	38,151	48,610.8	−10,459.8	−27.4	2,116	3781	−1665	−78.7
Red Sea	23,995	24,646.9	−651.9	−2.7	8,925	9382	−457	−5.1
Total	62,146	63,554	1408	2.3	10,949	12,447	−1498	−13.7

Source: Calculated from: 1- surplus production model in Table 3. 2- Ministry of Environment, Water, and Agriculture (2000–2019).

production from the Red Sea. In terms of the gap range details, the actual yield was less than the MSY by 2%–17% during the periods 2000–2006 and 2013–2019. In contrast, there was overfishing during the period of 2007 to 2011, which had a range of between 4.64% and 11.63%. These results indicate that the fishing effort that achieves the MSY is estimated at 9382 boats for the optimal fishing effort, which exceeds the average number of boats for the study period (8,925) by 5.1%. The actual fishing effort was less than the optimal fishing effort during the 2012–2019 period, in which the gap had a range of between 6.09% and 33.05%, while the actual fishing effort was above optimal for the rest of the study period with a range between 6.09% and 8.44%.

3.2.3. Total catches

The model of surplus production for the total fishery estimated that the MSY of fish production from all Saudi fisheries is 63,554 tons. The MSY exceeded the average actual catch in the study period (62,146 tons) by 2.3%, indicating that Saudi fisheries could increase production without harm to the sustainability of marine organisms and biodiversity. The actual fish production was below the MSY from 2000 to 2005, and 2013 by 1.8%. However, overfishing occurred during the study period ranging from 0.4% to 11.9%. Additionally, it was estimated that the fishing effort that achieves the MSY is 12,447 boats, which is higher than the average number of fishing boats used during the study period (10,949 boats) by 13.7%. In detail, the actual fishing effort exceeds the effort that achieves the maximum fishing effort by between 6% and 35% during the years 2000, 2001, 2002, and 2012–2019, and the opposite occurred in the rest of the study period whereas the maximum fishing effort exceeded the actual one by between 1% and 5%.

According to the above results of the function of fish production, there is evidence that fish production is in the second production stage, where it is the economic production stage. Therefore, there is an opportunity to increase production from Saudi fisheries to the optimal production point. This result agrees with the surplus production model, which indicates that there is still an opportunity to increase fish production in Saudi Arabia by increasing investment in the fishing sector through industrial fishing methods. We notice the decrease in the number of industrial fishing boats in the Arabian Gulf and an increase in the number of industrial fishing boats in the Red Sea because industrial fishing boats are large and need a large area to move within the Gulf's international waters while it is forbidden. Additionally, because of many oil projects in the Arabian Gulf, these boats cannot easily move in the Gulf water because that exposes them to violations and fines. Further, the huge amount of fish these boats need to catch to cover their operational expenses, while under these conditions, make their work unfeasible.

In contrast, the industrial boats in the Red Sea have more flexibility to cruise for long distances. Therefore, it is preferable to use medium-sized industrial fishing boats and traditional boats in the Arabian Gulf fisheries. The use of large industrial fishing boats in the Red Sea to achieve the MSY provides a balance between reproduction and fish losses to keep the fish resource from depletion.

4. Conclusions

This research aimed to identify the current status of marine fish production and most important climatic and environmental factors affecting production from natural fisheries and estimate the MSY in Saudi Arabia by focusing on the primary fisheries, including the Arabian Gulf and the Red Sea, during the period 2000–2019.

We found that the most important climatic and environmental factors affecting marine fish production in the country were the number of industrial fishing boats, number of fishers, and wind speed. Additionally, a significant positive relationship was found between the quantity of fish production in Saudi's fisheries and the number of industrial fishing boats and the number of fishers, whereas increasing these variables by 10% was found to lead to an increase in fish production in Saudi's fisheries by 6% and 1.8% respectively, which is consistent with economic logic. In contrast, there was an inverse relationship between wind speed and fish production in these fisheries, with a 10% increase in wind speed leading to a 6.8% decrease in fish production in Saudi Arabia. An increase in the wind speed leads to an increase in wave height and strength, creating an unsafe situation for fishers to refrain from fishing until the weather stabilizes. The total output elasticity is 0.10, which is less than 1, indicating that fish production in these fisheries is in the second production stage, whereas there is an opportunity to increase the production variables with diminishing return.

The study also used the Schaefer model to determine the fishing effort that achieves the MSY for the study period 2000–2019. For the Arabian Gulf fishery, the MSY is estimated as 48,610.8 tons, which exceeds the average of actual fish production during the study period by 27.4% over the average study period, indicating that there is an opportunity to increase production from Arabian Gulf catches. Our models also estimated that the optimal fishing effort that achieves the MSY in the Arabian Gulf is 3,781 boats, whereas the average of the actual fishing effort during the study period was less than the estimated optimal amount by 78.8%. It was also estimated that the MSY in the Red Sea fishery is 24,646.9 tons, which is larger than the average of actual fish production by 2.7% during the study period. Thus, there is an opportunity to increase production from the Red Sea. The optimal fishing effort found to achieve the MSY was 9,382 boats, which is larger than the average of the actual fishing effort during the study period by 5.1%. For all Saudi Arabia fisheries, the Schafer model estimated the MSY as 63,554 tons, which is larger than the study period's average by 2.3%. Therefore, there is an opportunity to increase production from all of Saudi's fisheries. Simultaneously, the optimal fishing effort that achieves the MSY is estimated at 12,447 boats, with a gap of 13.7% over the average study period.

As the production function showed that fish production in Saudi Arabia is in the second production stage, there might be an opportunity to increase production from Saudi's fisheries. The surplus production model results correspond with this conclusion, showing that fish production in Saudi's fisheries could be increased by increasing the fishing sector's investment to achieve the MSY and prevent the fish resource from depletion. There is an opportunity to increase the number of traditional fishing boats and medium-sized industrial fishing boats in the Arabian Gulf fisheries while using more large industrial fishing boats in the Red Sea fisheries.

Accordingly, the research recommends motivating young people to work and invest in the fishing sector by providing training institutes and developing incentives that encourage them to pursue fishing, such as health and retirement insurance. It is also necessary to provide sufficient information to the fishers on weather conditions and train them on ways to confront wind and weather changes that hinder fishers in their daily tasks at sea, which is one reason for fluctuations in local production. Additionally, developing the fishing profession and giving it attention leads to the availability of job opportunities for many people. The study found a gap between actual and sustainable production. However, economic production is when the marginal cost equals the average price. Therefore, the study recommends further research on economic production for each fish species.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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