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SELF-SUFFICIENCY OF THE TURKISH AQUACULTURE SECTOR AND FORECASTING ITS PRODUCTION WITH THE ARIMA (BOX-JENKINS) MODEL

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Abstract

With its seas and water resources, Türkiye's aquaculture industry plays a significant role in both the nation's economy and society's ability to eat healthily. The objectives of this study are to evaluate the level of self-sufficiency in aquaculture production, assess the developments in the aquaculture sector in Türkiye, and estimate the production amount for the next ten years employing the ARIMA (Autoregressive Integrated Moving Average) method using the aquaculture production amounts between 1950 and 2021. Making forecasts for the upcoming years is believed to be beneficial in terms of investment and production planning. The amount of aquaculture production was estimated with the Box-Jenkins ARIMA method. As a result of the analyses performed, the ARIMA (1, 2, 2) model was found to be the most suitable model for forecasting aquaculture production. According to the estimation, it is expected to increase by 17.29% between 2022 and 2031. It is believed that depending on this rise, actions should be taken to expand the aquaculture processing facilities associated with the aquaculture sector.

Key words*: *aquaculture, self-sufficiency, time series, Box-Jenkins method, Türkiye

INTRODUCTION

It has become vital to look for alternative protein sources because of factors such as the requirement for protein in human nutrition, the diminishing availability of terrestrial protein sources, the devastation of agricultural areas where animals are kept, and people's desire to consume more. Seafood tops the list of substitute protein sources due to its high protein concentration [8].

Animal foods are one of the most important sources of protein in human nutrition. Fish holds a prominent role among animal-derived foods in terms of nutritional value, particularly because of its high protein ratio. The protein content of fish meat ranges between 18% and 20%. Fish oil is a significant source of nutrition since it has the most omega-3 fatty acids when compared to other oils [12].

Türkiye has an essential place in aquaculture production with its seas, inland waters, lakes, and ponds. It is surrounded by water on three sides and contains 8,333 kilometres of coastline, 177,714 kilometres of rivers, and 342,377 hectares of dam lakes. The seas and inland waters have a combined surface area of 25 million hectares and are positioned near agricultural areas. In this context, active use of aquaculture resources is required. It is critical to protect these resources to get the maximum benefit from them in the future. There are 247 fish species in the Black Sea, 200 in the Marmara Sea, 300 in the Aegean Sea, and almost 500 in the Mediterranean Sea, with 100 of these species recognised as economically significant [3].

The various features of Türkiye's seas allow for both aquaculture and capture in certain waters. While the share of fisheries produced by capture has declined in recent years, the share of fisheries produced by aquaculture has increased.

Over the years, Türkiye's aquaculture industry has seen substantial growth. Estimating the amount of aquaculture production, which has a significant place in Turkish nutrition and the country's economy, for the following years is regarded as advantageous in terms of investment and production planning. The purpose of this study is to examine the developments in Türkiye's aquaculture sector between 2000 and 2021, to evaluate the level of self-sufficiency in aquaculture production, and to forecast production amounts for the next ten years using the Autoregressive Integrated Moving Average (ARIMA) method based on aquaculture production amounts between 1950 and 2021. It is believed that the study's findings will be beneficial to aquaculture producers, entrepreneurs looking to invest in this field, legislators, and researchers seeking to work in this field.

MATERIALS AND METHODS

Data

To analyse the Self-Sufficiency Ratio (SSR), the data on aquaculture export value ($), export quantity (tonnes), import value ($), import quantity (tonnes), and production amount (tonnes) were collected for a period of 61 years from 1961 to 2021 from the Food and Agricultural Organization of the United Nations [9]. From the FAO [9] database, data on aquaculture consumption (kg/per capita/yr) was also gathered. Academic studies from national and foreign scientific journals and books were also used.

Self-sufficiency index

Self-sufficiency in food seems to be a straightforward concept. If a nation can produce enough food to satisfy its own needs, it is considered food self-sufficient. In the 1960s, food self-sufficiency gained popularity and found success, even in industrialised nations. Self-production is the key element of food self-sufficiency. On the other side, food self-sufficiency relates to both the supply and the source of food. Theoretically, a nation's capacity to produce all of its food depends on its financial, economic, and natural resources, as well as its effective governance, sophisticated infrastructure and logistics systems, technological advancement, and effective agricultural plans and initiatives [6, 19].

A nation may strive for food self-sufficiency for several reasons, such as enhancing national pride, lowering susceptibility to external markets or specific nations, generating employment, or as a result of the rise of economic nationalism and patriotic leaders in a state. As can be seen, having food self-sufficiency is significant for a variety of reasons. Therefore, it is crucial to examine in the research the level of self-sufficiency of the Turkish aquaculture sector.

The Self-Sufficiency Ratio (SSR) is determined by the following formula [10]:

$$SSR = \frac{P*100}{P+M-X} \quad (1)$$

where:

M and X stand for imports and exports, respectively, and P stands for production.

Therefore, a country is considered self-sufficient in aquaculture production when the SSR is 100 or higher; otherwise (SSR<100), it is insufficient.

Box-Jenkins ARIMA approach

The Box-Jenkins [5] method is one of the approaches used in univariate time series to produce forward-looking estimations using statistical methods. The time series must be distinct, stationary, and evenly spaced for the method to function properly [2]. The three most frequent linear stationary Box-Jenkins models are autoregressive (AR), moving average (MA), and autoregressive moving average (ARMA), which combines AR and MA models [4]. The Box-Jenkins technique has a substantial advantage in that it can use past observation values as an explanatory variable. Box-Jenkins estimation methods are an experimental process, not a method defined by a model. They can choose the best model from a range of possibilities and track the suitability of the chosen model at each level.

An ARMA model is generally referred to as ARMA (p, q), where p and q are the autoregression and moving average orders, respectively. The time series is a linear function of actual previous values and random shocks in the ARMA model [11]. A stationary time series, ARMA (p, q), is defined by the equation:

$$Y_t = \alpha + \vartheta_1 Y_{t-1} + \vartheta_2 Y_{t-2} + \cdots + \vartheta_P Y_{t-p} + \epsilon_1 + \theta_1 \epsilon_{t-1} + \cdots + \theta_q \epsilon_{t-q} \quad (2)$$

where:

α is a constant term that represents the mean of Y. Y_t is the dependent variable at time t, and the independent variables at lags t-1, t-2, ..., t-p are denoted by Y_{t-1}, Y_{t-2},…, Y_{t-p}.

The coefficients to be estimated are denoted by ϑ s. The error terms are uncorrelated random variables with constant variance and zero means, denoted by ϵs. θs are estimated coefficients as well.

On stationary series, the AR, MA, and ARMA methods are employed. Thus, a non-stationary process must be made stationary. In this instance, the initial series is referred to as a homogeneous non-stationary series. By taking the difference to a suitable degree, a non-stationary time series can be rendered stationary and follow the autoregressive integrated moving average [ARIMA (p, d, q)] processes. In this context, the letter d stands for integration (difference). Stationarity can be confirmed visually by inspecting the data graph, the structure of the autocorrelation, and the partial correlation coefficients. Unit root tests are another approach to assessing stationarity. If it is discovered that the model is non-stationary, differencing the series will bring it into stationarity. The unit root test Augmented Dickey-Fuller (ADF) [7] was employed in the study to attain this goal. In addition, autocorrelation function (ACF) and partial autocorrelation function (PACF) graphs were generated to visually define what type of development the series contained.

The identification procedure selects the initial values for the orders of parameters (p and q) after establishing whether the series is stationary. One or more models that appear to provide statistically adequate representations of the appropriate data are tentatively chosen during the identification step. The model's parameters are then carefully estimated using least squares.

For several AR and MA combinations, various models are run independently and simultaneously. The best model is determined by low Akaike (AIC) or Schwarz (SIC) information criteria, the absence of residual autocorrelations, and the relevance of the parameters. Akaike [1] and Schwarz [13] proposed information criteria to select between time series models. The delayed order with the lowest values is regarded as the proper delay order. Consequently, the model with the lowest value of the information criteria is selected.

RESULTS AND DISCUSSIONS

The development of Türkiye's aquaculture sector and its self-sufficiency assessment

As mentioned earlier, the different features of Türkiye's seas enable both capture and aquaculture. Table 1 shows the amounts of aquaculture products produced in Türkiye by capture and aquaculture methods between the years 2000 and 2021. While Türkiye produced 582,376 metric tonnes of aquaculture in 2000, it reached 799,844 metric tonnes in 2021, showing a 37.34% increase. During the same time span, while the amount of aquaculture produced by aquaculture increased approximately six-fold, the amount of aquaculture produced by capture methods decreased by 34.80%. The reasons for the decrease in aquaculture production via the capture method can be overfishing, improper capture, destruction of natural habitats, climate change, and pollution of waters due to chemicals and heavy metals. Among the reasons for the increase in aquaculture production via the aquaculture method can be an increase in aquaculture demand, advancements in technological tools and methods used for aquaculture, an increase in productivity, the high export potential of aquaculture, and aquaculture-friendly regulations. According to data from 2021 in Türkiye, while aquaculture production accounted for 58.97% of overall aquaculture production, capture production accounted for 41.03%. In the same year, 78.85% of the total aquaculture production was obtained from the seas and 21.15% from inland waters. Fish species constituted 95.66% of the total aquaculture production, and other aquaculture products constituted 4.34%.

Türkiye has a strong position in terms of capture, given its current water resources and potential. In this regard, the number of fish species obtained by the capture method is also quite high. Türkiye’s capture potential is especially essential for aquaculture because fish meal and oil used in fish feed are derived from capture production [14]. In 2021, anchovies constituted approximately half of the overall production (328,158 metric tonnes), with a share of 46.20% of the total aquaculture production.

Table 1. Aquaculture and capture production amounts in Turkish aquaculture production

Year	Capture (tonnes)			Aquaculture (tonnes)			Overall
	Marine	Inland water	Total	Marine	Inland water	Total	Total
2000	460,521	42,824	503,345	35,646	43,385	79,031	582,376
2001	484,410	43,323	527,733	29,730	37,514	67,244	594,977
2002	522,744	43,938	566,682	26,868	34,297	61,165	627,847
2003	463,074	44,698	507,772	39,726	40,217	79,943	587,715
2004	504,897	45,585	550,482	49,895	44,115	94,010	644,492
2005	380,381	46,115	426,496	69,673	48,604	118,277	544,773
2006	488,966	44,082	533,048	72,249	56,694	128,943	661,991
2007	589,129	43,321	632,450	80,840	59,033	139,873	772,323
2008	453,113	41,011	494,124	85,629	66,557	152,186	646,310
2009	425,046	39,187	464,233	82,481	76,248	158,729	622,962
2010	445,680	40,259	485,939	88,573	78,568	167,141	653,080
2011	477,658	37,097	514,755	88,344	100,446	188,790	703,545
2012	396,322	36,120	432,442	100,853	111,557	212,410	644,852
2013	339,047	35,074	374,121	110,375	123,019	233,394	607,515
2014	266,078	36,134	302,212	126,894	108,239	235,133	537,345
2015	397,731	34,176	431,907	138,879	101,455	240,334	672,241
2016	301,464	33,856	335,320	151,794	101,601	253,395	588,715
2017	322,173	32,145	354,318	172,492	104,010	276,502	630,820
2018	283,955	30,139	314,094	209,370	105167	314,537	628,631
2019	431,572	31,596	463,168	256,930	116,426	373,356	836,524
2020	331,281	33,119	364,400	293,175	128,236	421,411	785,811
2021	295,018	33,140	328,158	335,644	136,042	471,686	799,844
2000=100	64.06	77.39	65.20	941.60	313.57	596.84	137.34

Source: Turkish Statistical Institute [15].

It is a common species in the seas off Türkiye. Anchovy populations may expand due to reproduction and rapid growth when compared to other fish. Sprat and horse mackerel accounted for 8.54% and 7.32% of the total aquaculture production, respectively (Figure 1).

Figure 2 shows the primary fish species farmed in Türkiye in 2021. The share of aquaculture products obtained through aquaculture in overall aquaculture production in Türkiye exceeded the share of aquaculture products obtained through capture.

Trout, sea bass, and sea bream took the first three places in aquaculture (471,686 metric tonnes) produced through aquaculture in Türkiye’s seas and inland waters in 2021. The shares of these species were 35.47%, 32.89%, and 28.30%, respectively. The fish species in question constituted 96.66% of the total production.

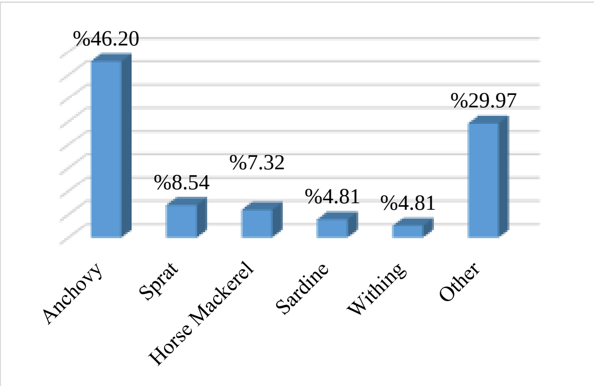

Fig. 1. The amount of capture production for the major fish species (tonnes)
Source: Graphed by the author using the data from Turkish Statistical Institute [15].

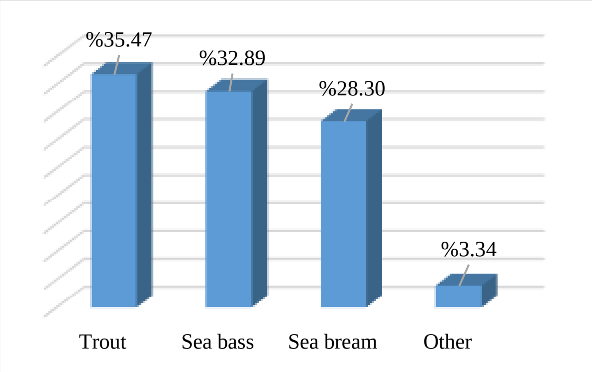

Fig. 2. The amount of aquaculture production for the major fish species (tonnes)
Source: Graphed by the author using the data from Turkish Statistical Institute [15].

The developments in Türkiye's foreign trade in aquaculture products are given in Table 2. As seen in the table, aquaculture product exports, which were 14,533 metric tonnes in 2000, increased 16.43 times and reached 238,732 metric tonnes in 2021.

The export value of aquaculture products increased 29.68 times in the same period, reaching 1.376 billion dollars.

The increase in Türkiye's aquaculture production was also reflected in exports. Incentives for exporters, in particular, were effective in increasing exports. While aquaculture product imports in Türkiye were 44,230 metric tonnes in 2000, they climbed 2.37 times to 104,708 metric tonnes in 2021. Regarding the import value of aquaculture products, it was approximately 37 million dollars in 2000 and increased by 5.93 times, reaching 217 million dollars in 2021.

Aquaculture consumption per capita and the self-sufficiency index in Türkiye are given in Table 3. While the per capita consumption of aquaculture products was 8.0 kilogrammes in 2000, it decreased by 17.75% to 6.6 kilogrammes in 2021.

Table 2. Aquaculture foreign trade in Türkiye

	Export		Import	
Year	Amount (tonnes)	Value ($)	Amount (tonnes)	Value ($)
2000	14,533	46,374,937	44,230	36,647,254
2001	18,978	54,487,312	12,971	11,295,373
2002	26,860	96,728,389	22,532	18,754,783
2003	29,937	124,842,223	45,606	32,636,120
2004	32,804	180,513,989	57,694	54,240,304
2005	37,655	206,039,936	47,676	68,558,341
2006	41,973	233,385,315	53,563	83,409,842
2007	47,214	273,077,508	58,022	96,632,063
2008	54,526	383,297,348	63,222	119,768,842
2009	54,354	318,063,028	72,686	105,822,852
2010	55,109	312,935,016	80,726	133,829,563
2011	66,738	395,306,914	65,698	173,886,517
2012	74,006	413,917,190	65,384	176,402,894
2013	101,063	568,207,316	67,530	188,068,388
2014	115,381	675,844,523	77,551	198,273,838
2015	121,053	692,220,595	110,761	250,969,660
2016	145,469	790,303,664	82,074	180,753,629
2017	156,681	854,731,829	100,444	230,111,248
2018	177,500	951,793,070	98,315	188,965,220
2019	200,226	1,025,617,723	90,684	189,438,745
2020	201,375	1,064,877,338	85,269	156,929,169
2021	238,732	1,376,291,922	104,708	217,179,174
2000=100	1642.69	2967.75	236.74	592.62

Source: Turkish Statistical Institute [16].

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Table 3. Aquaculture consumption per capita and self-sufficiency index in Türkiye

Year	Production	Consumption per capita (kg)	Import amount (tonnes)	Export amount (tonnes)	Self-sufficiency ratio
2000	582,376	8.0	44,230	14,533	95.15
2001	594,977	7.5	12,971	18,978	101.02
2002	627,847	6.7	22,532	26,860	100.69
2003	587,715	6.7	45,606	29,937	97.40
2004	644,492	7.8	57,694	32,804	96.28
2005	544,773	7.2	47,676	37,655	98.19
2006	661,991	8.2	53,563	41,973	98.28
2007	772,323	8.6	58,022	47,214	98.62
2008	646,310	7.8	63,222	54,526	98.67
2009	622,962	7.6	72,686	54,354	97.14
2010	653,080	6.9	80,726	55,109	96.23
2011	703,545	6.3	65,698	66,738	100.15
2012	644,852	7.1	65,384	74,006	101.36
2013	607,515	6.3	67,530	101,063	105.84
2014	537,345	5.5	77,551	115,381	107.64
2015	672,241	6.1	110,761	121,053	101.55
2016	588,715	5.5	82,074	145,469	112.07
2017	630,820	5.5	100,444	156,681	109.79
2018	628,631	6.1	98,315	177,500	114.41
2019	836,524	6.3	189,438	200,226	115.07
2020	785,811	6.8	156,929	201,375	117.30
2021	799,844	6.6	217,179	238,732	120.13

Source: Turkish Statistical Institute [16] and author's calculation.

A country's self-sufficiency ratio in aquaculture shows whether the amount produced in that country is sufficient to meet its needs. A self-sufficiency ratio of 100 or more indicates that the country is self-sufficient.

It is seen that Türkiye's self-sufficiency index in aquaculture products was at its lowest level at 95.15 in 2000. After 2010, a significant increase in the self-sufficiency ratio started and increased to 120.13 in 2021. This result shows that Türkiye is self-sufficient in aquaculture and has export potential in it.

Forecasting Türkiye's aquaculture production amounts with the ARIMA model

The annual time series from 1950 to 2021 was employed to forecast the amount of aquaculture production in Türkiye. While aquaculture production in Türkiye was 89,700 metric tonnes in 1950, it increased 8.92 times and reached 799,844 metric tonnes in 2021. The course of the 1950–2021 period used in estimating aquaculture production in Türkiye until 2031 with the ARIMA (Box–Jenkins) model is given in Figure 3.

Figure 3 shows how the amount of aquaculture production in Türkiye has fluctuated over time. Autocorrelation (ACF) and partial autocorrelation (PACF) graphs were used to see this more clearly and determine its stationarity.

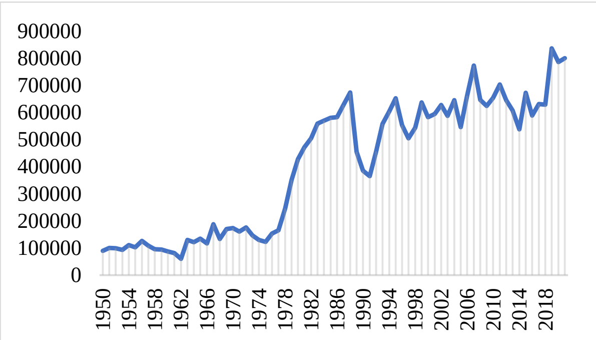

Fig. 3. Aquaculture production amount in Türkiye by years (tonnes)
Source: Food and Agricultural Organization [9] and Turkish Statistical Institute [15].

The series is not stationary in the ACF graph because several lags exceed the confidence limits. In this case, the series should be de-trended using the first- order difference to make it stationary. However, the series did not become stationary in the first-order difference process, and differentiation was repeated. The ACF and PACF graphs of the series with a second-degree difference are presented in Figure 4. In addition to visual inspection, statistical tests can be used to examine stationarity. Therefore, the Augmented Dickey-Fuller (ADF) test was used to determine if the series is stationary. The ADF test determines whether the series has a unit root. The existence of a unit root shows that the series is not stationary.

As a result of the ADF test at level, the series was not stationary. After taking the second difference, the ADF test revealed that the series was stationary; in other words, it did not contain a unit root. Thus, the degree of integration in the ARIMA (p, d, q) model was determined as I(2). When the ADF results of Türkiye's aquaculture production values were examined, it was clear that the series had a unit root since the absolute value of the test statistic (-0.897959) was less than the absolute critical values. P-value of 0.7835 in the analysis, so >0.05, indicates that the series is not stationary. For this reason, the series was made stationary by taking the differences before the estimation process. It was seen that the absolute value of the ADF test statistic (-9.093846) for the aquaculture production, which became stationary after the second-order differences were taken, was greater than the critical values. Also, a significance level (0.000) less than 0.05 indicates that the series becomes stationary and can be used for estimation with ARIMA (Table 4).

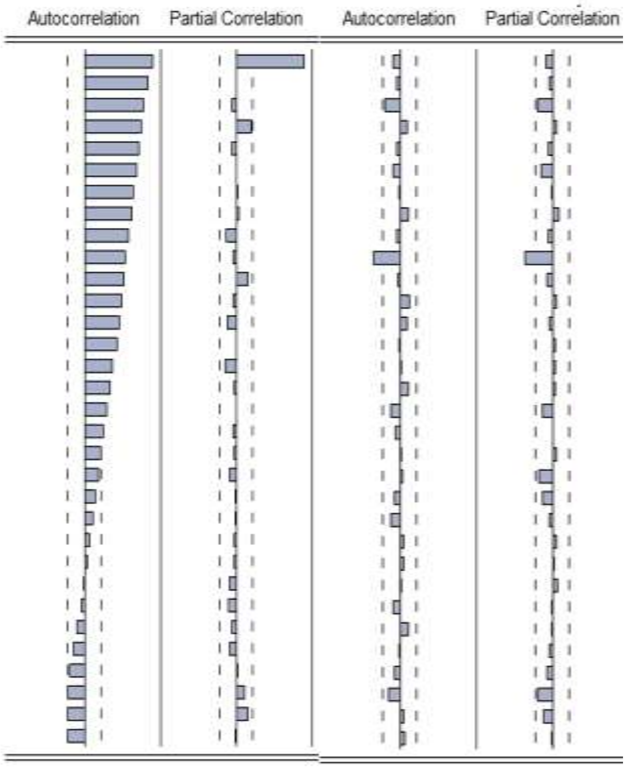

Fig. 4. ACF and PACF graphs of non-stationary and quadratic differenced series
Source: author's calculation.

Among the ARIMA models, the best statistical result was obtained with the ARIMA (1, 2, 2) model, which became stationary at the 2nd difference and showed that the 1st-order lag and 2nd-order error terms were related to their past values. Accordingly, all variables were found to be statistically significant, and the R-squared value of the model was 0.54 (Table 5).

The ADF unit root test was applied to the series of residual values to determine the accuracy of the model obtained, and the hypothesis "H0=there is a unit root" was rejected. Therefore, the model proved to be significant (Table 6).

Table 4. ADF unit root test results for aquaculture production

		t-statistic	p-value			t-statistic	p-value
I(0)		-0.897959	0.7835	I(2)		-9.093846	0.000
Critical values	1%	-3.525618		Critical values	1%	-3.531592	
	5%	-2.902953			5%	-2.905519	
	10%	-2.588902			10%	-2.590262	

Source: author's calculation.

Table 5. Results of the ARIMA (1, 2, 2) model of aquaculture production

TYPE	Coefficient	Std. error	p-value
C	95.93604	343.8059	0.7811
AR(1)	-0.999993	0.333938	0.0039*
MA(2)	-0.999272	0.016210	0.0000*
R-squared	0.543500		
F-statistics	26.19277		
AIC	25.16270		
SIC	25.29119		
HQ	25.21374		
Durbin Watson stat.	2.150504		

Source: author's calculation.

Table 6. ADF unit root tests for residuals of the aquaculture production estimation model

		t-statistic	p-value
		-8.830677	0.000
Critical values	1%	-3.528515	
	5%	-2.904198	
	10%	-2.589562	

Source: author's calculation.

The aquaculture production estimation results of the ARIMA (1, 2, 2) model are shown in Figure 5.

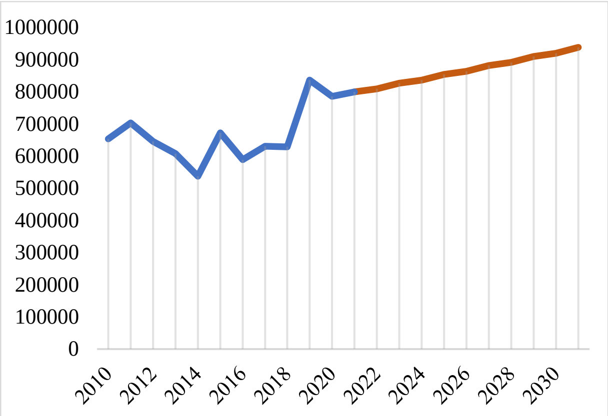

Fig. 5. Actual (1910-2021) and forecasted (2022-2031) data graphs for aquaculture production in Türkiye
Source: author's calculation.

The amount of aquaculture production in Türkiye is expected to increase between 2022 and 2031. Aquaculture production is projected to increase by 17.29% to 938,145 metric tonnes by 2031, from 799,844 metric tonnes in 2021 (Table 7).

Table 7. The aquaculture production forecast for the years 2022–2031 (tonnes)

Year	Predicted production
2022	809,124
2023	826,742
2024	836,208
2025	854,017
2026	863,674
2027	881,676
2028	891,525
2029	909,718
2030	919,760
2031	938,145

Source: author's calculation.

According to TSI's population projection research, Türkiye's population will be 88,929,672 in 2031 [17]. Because of the predicted increase in aquaculture productivity and population, it is thought that effective investment planning and production policies will be beneficial.

CONCLUSIONS

In terms of high protein and omega-3 fatty acids, aquaculture products are a significant source of nutrients in an adequate and balanced diet. Türkiye holds an important position in terms of available water resources and aquaculture production.

The total amount of aquaculture obtained through capture and aquaculture in Türkiye was 799,844 metric tonnes in 2021, of which 41.03% was obtained by capture and 58.97% by aquaculture. In the same period, 78.85% of total aquaculture production was obtained from the sea and 21.15% from inland waters. In 2021, 95.66% of the total aquaculture production in Türkiye was composed of fish species and 4.34% of other aquaculture products. The share of anchovy in the total aquaculture production (328,158 metric tonnes) in Türkiye in 2021 was 46.20%, while the shares of sprat and horse mackerel were 8.54% and 7.32%, respectively. Trout had a 35.47% share of overall aquaculture (471,686 metric tonnes), while sea bass and sea bream had 32.89% and 28.30%, respectively. Aquaculture consumption per capita in Türkiye was 6.6 kilogrammes in 2021.

After 2010, the self-sufficiency ratio of aquaculture production in Türkiye began to rise significantly, reaching 120.13 in 2021. Aquaculture production data from 1950 to 2021 was used in the ARIMA approach. Türkiye's aquaculture production has fluctuated. ACF and PACF graphs were employed to show this more clearly and determine its stationarity. The series was not stationary in the ACF graph because several lags exceeded the confidence limits. Also, the ADF unit root test indicates whether the series has a unit root. According to the ADF test results, the series contained a unit root, indicating that it was not stationary. Therefore, before the estimation phase, the aquaculture production series was converted to a stationary series using the second-order differencing approach. The ADF unit root test was employed for this, and the test statistic was -9.093846. The best statistical result was obtained with the ARIMA (1, 2, 2) model, as it remained stationary at the second difference and demonstrated that the first-order lag and second-order error terms were related to past values. All variables in the model were found to be statistically significant, and the model's R-squared value was 0.54.

According to the findings of the study, aquaculture production in Türkiye is predicted to expand during the next ten years. Aquaculture production was estimated to increase by 17.29% to 938,145 metric tonnes by 2031 from 799,844 metric tonnes in 2021. As a result of this foresight, it is thought that increasing aquaculture processing facilities and developing appropriate investment plans and production policies will be beneficial due to the expected increase in aquaculture production and Türkiye's population.

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