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Trend analysis and future forecasting of marine capture fisheries production of Turkey

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Abstract

This study aimed to monitor marine capture fisheries production of Turkey currently available provided by the authorities. Hence, marine fishery production was monitored using the statistical data provided by the Turkish statistical institute between 2000 and 2018. Total marine capture fisheries production was calculated by the data on landings of fishery products as 460521 tons in 2000 and 283954.80 tons in 2018. Most of the total production is covered by fish species. In 2000, the production amount was 441690 tons (95.91%) for fish species while it was 18831 tons (4.09%) for other marine species. Although the production amount of other marine species has increased in 2018 (619331 tons, 21.81% of the total production) compared to the amount in 2000 (18831 tons), a large part of the production amount (222023 tons, 78.19%) is still covered by fish species. A very significant decrease (38.34%) was observed in the total production amount between 2000 and 2018. This decrease could be related to overfishing, habitat degradation, pollution, climate change, and anthropogenic/natural drivers. Climate change can critically affect ecosystem dynamics, lead to eutrophication and over-exploitation. Over-exploitation can prevent the regeneration of fish stocks. Natural or anthropogenic drivers can damage fish stocks and ecosystem services by habitat destruction. Therefore, the monitoring and regulation of fisheries activities are essential for the sustainability of marine fisheries resources. Regional efforts should be scheduled in terms of responsible fisheries management and ecosystem approached fisheries management in order to ensure the sustainability of marine fisheries resources. Local authorities, policy makers, and fisheries managers should increase their performance and implement measures, improve strengthen fisheries laws and regulations, and they should be capable of taking effective action to maintain ecosystems healthy, to sustain fish populations and marine fisheries productivity for future generations.

Keywords: Marine; Fisheries; Production; Prediction; Trend analysis.

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1. Introduction

Fish is an important source of protein, minerals, and essential amino acids. The amount of marine fisheries and aquaculture production can provide fish for the human nutrition in the future, and it is partly influenced by climate-driven variations in ecosystem productivity (Brander, 2007; Cheung *et al*., 2009a; 2009b), the efficiency of fisheries management policies (Kale, 2019), and the capacity expanding of aquaculture by reducing negative impacts on the marine environment (Naylor *et al*., 2009). Marine capture fishery is under pressure of the habitat degradation (Turner, 1999), illegal fishing (Perry *et al*., 2005), overexploitation of fishery resources (Kale, 2019). Positioning fisheries for protecting the ecosystem and livelihood have need of much more than avoiding the overfishing (Grafton *et al*., 2008). Although there are some successfully managed fisheries (Hilborn, 2007), several fisheries are poorly managed or not managed effectively. Future patterns of fisheries production is estimated to be affected by climate change (Kale, 2019). Potential impact of climate change is anticipated as shifting in the production by migrating of the species to new habitats (Cheung *et al*., 2009a; Cheung *et al*., 2009b) or as variations in the net marine primary production (Brander, 2007; Cheung *et al*., 2009a). On the other hand, Merino *et al*. (2012) reported that climate change effects on capture fisheries production could not be the most important reason in obtaining fish availability in the near future.

Globally, the effects of demand drivers and climate change on marine fisheries production were examined using several numerical models. Production vicissitudes in the catchable part of the ecosystem were estimated through applying the downscaling models of the physical-ecosystem model using the ERSEM ecosystem model by Blackford *et al*. (2004), POLCOMS hydrodynamic model coupled to the ERSEM ecosystem model by Holt and James (2006), and a size-based ecosystem model by Blanchard *et al*. (2009). Determination of patterns and trends in marine capture fisheries is an importance issue to monitor and to ensure the sustainability of marine fisheries resources. Trend analysis methodology is a frequently used method in statistical analysis for time series economical, hydrometeorological, geophysical, environmental, and climatic dataset (Box and Jenkins, 1976; Şen, 2012; Ejder *et al.*, 2016a; Ejder *et al*., 2016b; Kale *et al.*, 2016a; Kale *et al.*, 2016b; Kale *et al.*, 2018; Şen *et al.*, 2019; Arslan *et al.*, 2020; Sönmez and Kale, 2020). However, there is no study on the evaluation of the trends and future forecasting of marine capture fisheries production in Turkey. Therefore, the aim of the present paper is to determine the trends in marine capture fisheries production and to develop forecasting models of marine capture fisheries production in Turkey.

2. Materials and methods

2.1. Data

Data examined in the present paper include the production amounts of marine capture fisheries in Turkey between 2000 and 2018. The data was acquired from the website of Turkish Statistical Institute (TurkStat, 2020) by dynamic inquiries of fishery statistics.

2.2. Change-Point Analysis

The non-parametric change-point analysis was firstly proposed by Pettitt (1979) with the purpose of distinguish important changes in the means of a time series. Change-point analyses were executed by using R statistical software (R Core Team, 2020). The formulae given in Equation (1) and (2) are used for change-point analysis:

$$K_T = max|U_{t.T}|, \text{ and for } t = 2\ldots\ldots T; \quad (1)$$

$$U_{t.T} = \sum_{i=1}^{t} \sum_{j=t+1}^{T} sgn(x_i - x_j) \quad (2)$$

In Equations (1) and (2), K_T is the null hypothesis, U_{tT} checks whether two variables ($x_1, \ldots, x_t$ and $x_t+1, \ldots, x_T$) are in the same population or not. Associated probability (*p*) is used to calculate the level of significance.

2.3. Trend Analysis

2.3.1 Box and Jenkins method

Box and Jenkins (1976) proposed a method that was described as an autoregressive integrated moving average (ARIMA) model to detect the best fit of a time-series model to historical values of the time series. This method was applied with the purpose of determining the trend in the time series of marine capture fisheries production amounts dataset. Trend analyses were performed in Minitab and SPSS statistical software. Furthermore, autocorrelation analyses were executed to evaluate the steadiness of outputs. The ARIMA model used in the study is calculated using Equation (3).

$$X_t = c + \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + \theta_1 e_{t-1} + \theta_q e_{t-q} + e_t \quad (3)$$

In Equation (3), the variable will be defined in *t* time is X_t, the error in *t* time is e_t, the coefficient of per *q* parameter is θ, the coefficient of per *p* parameter is Φ, and the constant is *c*.

Principally, the order of scores and differencing of the AR and MA were found by using autocorrelation function (ACF) and partial autocorrelation function (PACF). Then, to check the residuals are white noise, the parameters were predicted. In the third step, the best fitting model was achieved in excess of residuals analysis. Ljung-Box test statistic values were used to validation of the randomness. Various ARIMA models were developed and compared with each other. ARIMA model with minimum normalized Bayesian Information Criterion (BIC), *p* and R-squared values were preferred as the best fit model and applied to estimate future trends in the marine capture fisheries production in Turkey. The accuracy of models was assessed by using commonly used performance measures (root mean square error, RMSE; mean absolute error, MAE; and mean absolute percentage error, MAPE).

2.3.2 Innovative trend analysis method

Innovative trend analysis methodology was originally suggested by Şen (2012). Time series is initially arranged from the past to the latest date, and then dataset is separated into two equal shares in the proposed method. Both sets are independently arranged again in ascending order. The plotting is carried out on the Cartesian coordinate system, and the first part of the time series is placed on the horizontal *X*-axis, and the second part is placed on the vertical *Y*-axis. If data are located on the 1:1 (45°) line, it specifies that there is no trend. On the contrary, if data are positioned on the upper/lower area of the 1:1 line, it specifies that there is increasing/decreasing trend in specified time series (Şen, 2012; Şen, 2014). The null hypothesis is that there is no statistically significant increasing/decreasing trend. Quite the reverse, the alternative hypothesis is the presence of a statistically significant increasing/decreasing trend in the specified time series.

2.3.3 Mann-Kendall and Spearman's Rho Test

Mann-Kendall test is a broadly executed test to observe a trend in a time series. This non-parametric test has an advantage that the data do not need to trail any definite distribution (Mann, 1945; Kendall, 1955). It is calculated using Equation (4).

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} sgn(x_k - x_i) \tag{4}$$

In this equation, the time series x_i is from i = 1, 2, …, n-1, and x_k from k =i + 1, …, n. Normalized test statistic is computed using Equation (5):

$$Z_c = \begin{cases} \dfrac{S-1}{\sqrt{var(S)}} & S > 0 \\ \dfrac{S+1}{\sqrt{var(S)}} & S = 0 \\ & S < 0 \end{cases} \tag{5}$$

In this equation, the test statistic is Z_c and while $|Z_c| > Z_{1-\alpha/2}$, wherein $Z_{1-\alpha/2}$ are the standard normal parameters and α is the level of significance for the test, H_0 will be rejected. The magnitude of the trend is computed using Equation (6).

$$\beta = \text{Median}\left(\frac{x_i - x_j}{i-j}\right).\ \forall_j < i.\ \text{ where } 1 < j < i < n \tag{6}$$

A negative value of β specifies a decreasing trend, while a positive value of β specifies an increasing trend.

Non-parametric Spearman's rho test was used to calculate the strength of a monotonic relationship between two parameters (Lehmann, 1975; Sneyers, 1990). Non-parametric Mann-Kendall test and Spearman's rho test advise more straightforward consequences than parametric tests (Kale and Sönmez, 2018a). Sen's slope estimation values were also determined according to Sen (1968).

3. Results

Pre-whitening processes were not implemented to the dataset and raw data was used to keep the originality of the time series in the trend analysis methodology. Table 1 describes the basic statistics of the time series. Table 2 provides the results of the tests of Mann-Kendall and Spearman's rho, and the estimates of the Sen's slope statistics.

The normality of the dataset was analysed by Kolmogorov-Smirnov test and Shapiro-Wilk test. The null hypothesis is that the sample data are not significantly different from a normal population. On the other hand, the alternative hypothesis is that the sample data are significantly different from a normal population. The statistics of the normality tests were found 0.136 and 0.965 by Kolmogorov-Smirnov (with Lilliefors significance correction) and Shapiro-Wilk tests. The p-values for both tests were found 0.200 and 0.674 for Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively. The results of the normality test showed that the data presents a normal distribution. Subsequently, non-parametric Mann-Kendall test and Spearman's rank correlation test were applied to the dataset. The results of the tests were given in Table 2. Sen's slope values were estimated -11791.48, -12977.95, and 1156.307 for total marine fisheries production, marine fish production, and other marine species production, respectively.

Change point analysis results specified that the change point of the time series of total

Table 1. Descriptive statistics of time series data

Statistics	Values		
	Total Production	Marine Fish Production	Other Marine Species Production
Minimum Value	266077.600	222023.600	18831.000
Maximum Value	589129.000	518201.000	80685.500
Mean	421178.300	372991.495	48186.805
Standard Error	20149.393	20303.809	3907.644
Standard Deviation	87829.167	88502.254	17033.025
Coefficient of Variation	0.209	0.237	0.353
Skewness	-0.216	-0.230	0.239
Standard Error of Skewness	0.524	0.524	0.524
Coefficient of Skewness	6411676.852	5002510.396	391533.834
Kurtosis	-0.588	-0.981	0.065
Standard Error of Kurtosis	1.014	1.014	1.014

Table 2. The values of statistical parameters for marine fisheries production of Turkey

Dataset	Statistical Parameters	Values	Trend
Total Production	Kendall's tau	-0.567	▼
	p	0.0007833 0.000429	
	Spearman's rho	-0.763	▼
	p	0.0002194	
	Sen's slope	-11791.48	▼
Marine Fish Production	Kendall's tau	-0.637	▼
	p	0. 0001578	
	Spearman's rho	-0.825	▼
	p	0.000	
	Sen's slope	-12977.95	▼
Other Marine Species Production	Kendall's tau	0.205	↑
	p	0.2342	
	Spearman's rho	0.316	↑
	p	0.188	
	Sen's slope	1156.307	↑

Note: ▼ indicates statistically insignificant decreasing trend
↑ indicates statistically insignificant increasing trend

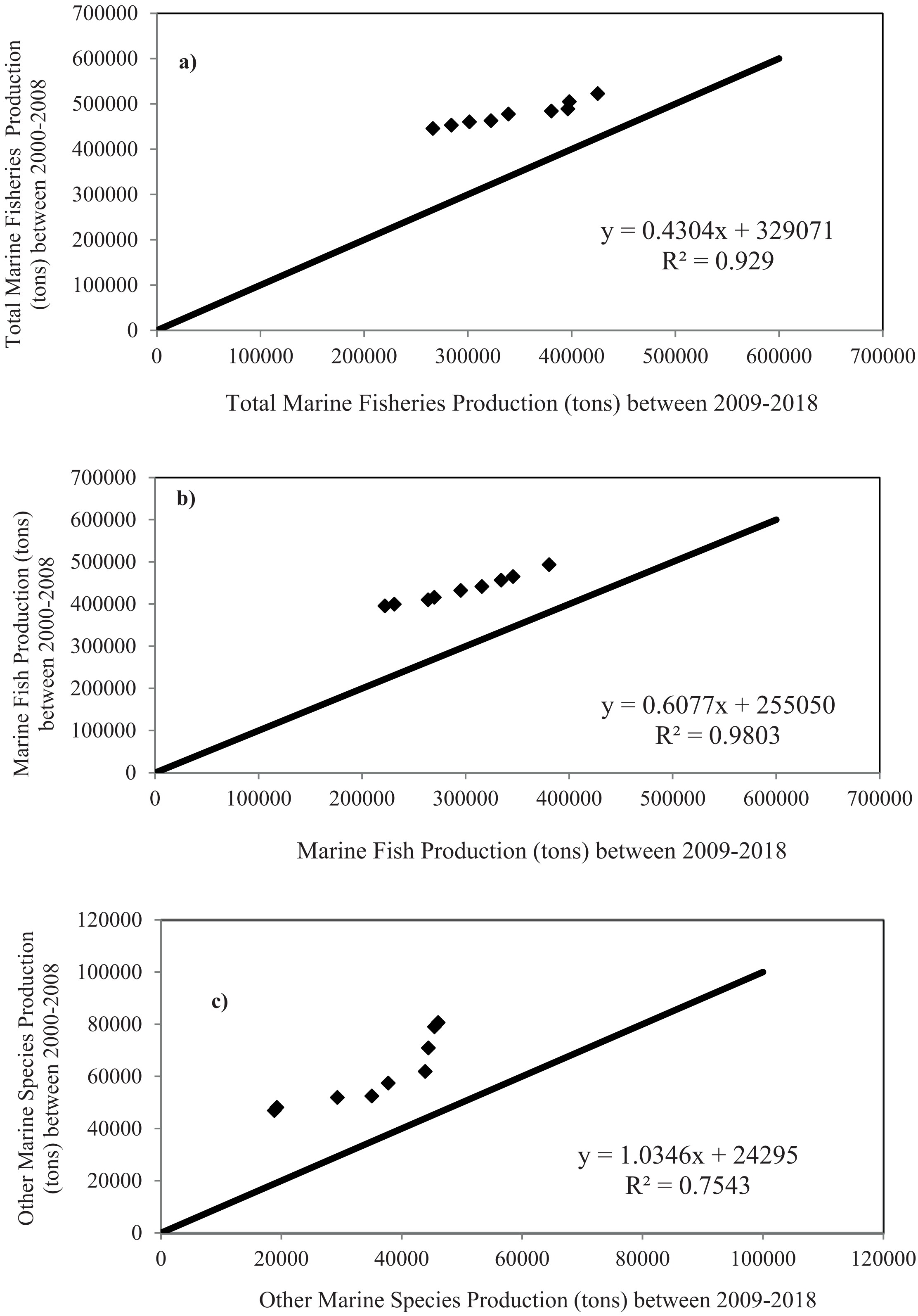

Figure 1. Scatter diagrams of the Şen's innovative trend analysis results for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

production was 2011. Similarly, change point was detected 2011 for the time series of marine fish production. On the other hand, change point analysis directed to 2002 for the time series of production of other marine species.

Results of the Şen's innovative trend test are given in Figure 1. The results of the innovative trend analysis methodology revealed that marine fisheries production in Turkey has a monotonic increasing trend (Figure 1a). Similarly, marine fish production (Figure 1b) and other marine species production (Figure 1c) have also increasing trend according to the results of Şen's innovative trend analysis.

Box and Jenkins (1976) recommended that the run-through of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) in place of the chief analyses to elect model order of ARIMA. The results of ACF and PACF of ARIMA (0,1,1), ARIMA (1,1,1), ARIMA (1,0,1), ARIMA (1,1,0), ARIMA (1,2,1), and ARIMA (2,1,2) models were displayed in Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7, respectively.

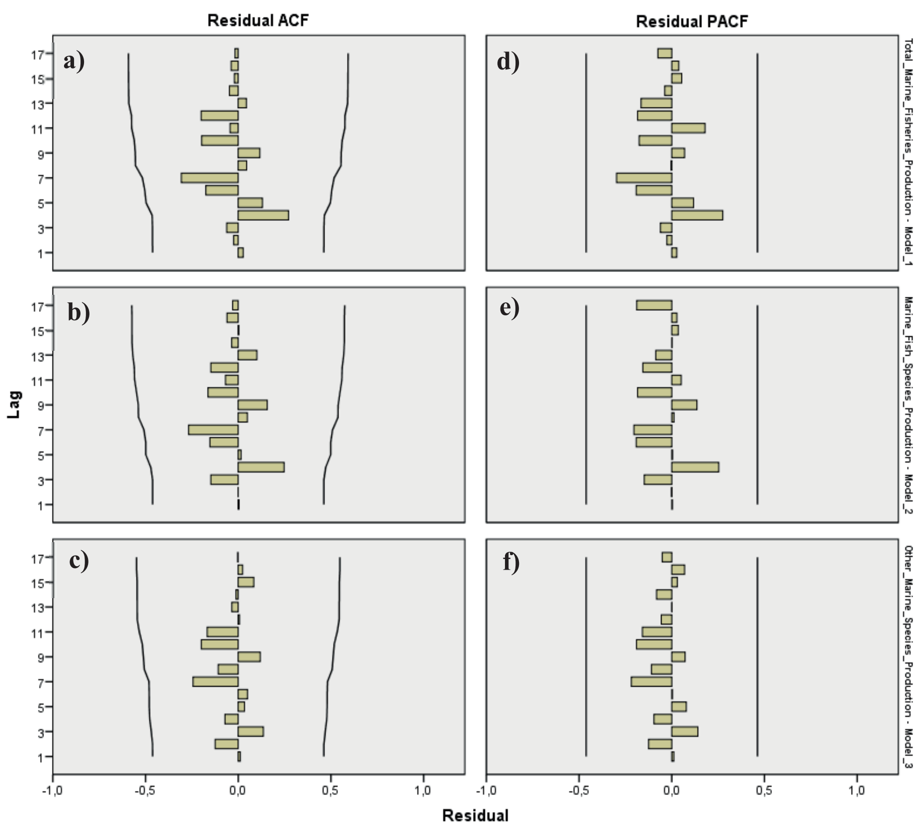

Figure 2. Residuals of autocorrelation functions of ARIMA (0,1,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production; residuals of partial autocorrelation functions of ARIMA (0,1,1) model for (d) total marine fisheries production, (e) marine fish production, and (f) other marine species production in Turkey

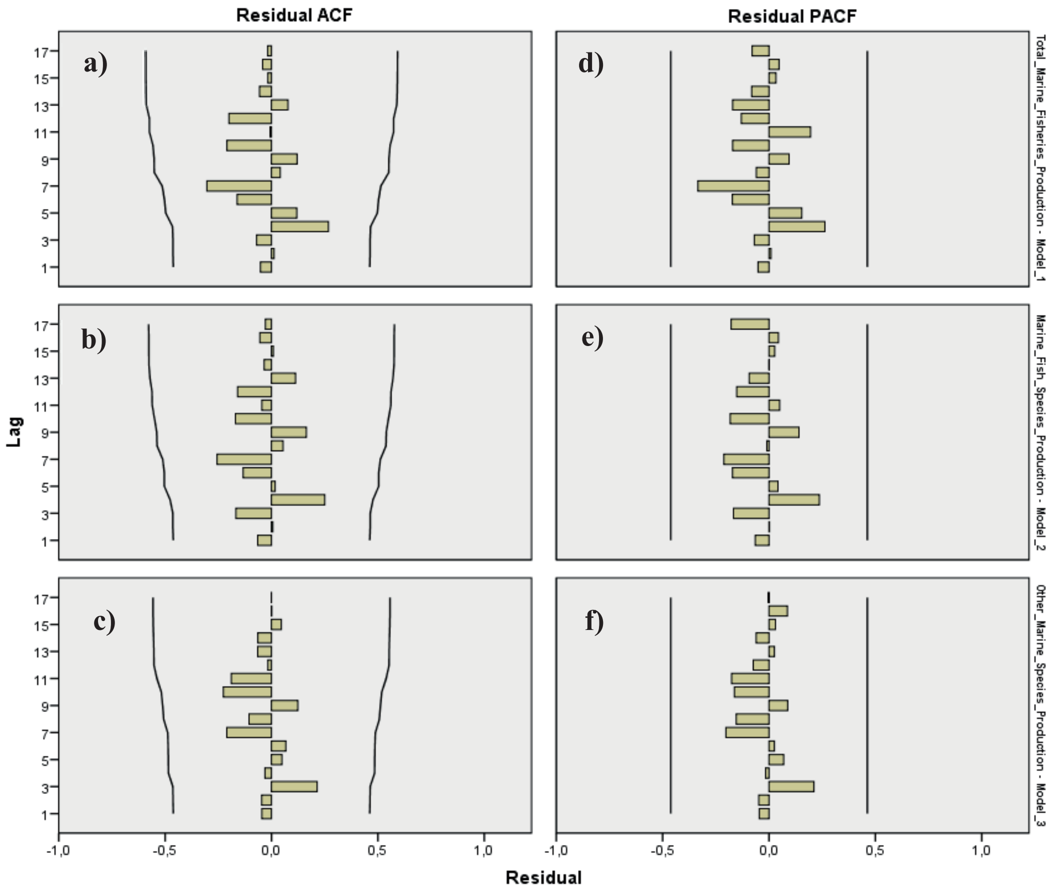

Figure 3. Residuals of autocorrelation functions of ARIMA (1,1,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production; residuals of partial autocorrelation functions of ARIMA (0,1,1) model for (d) total marine fisheries production, (e) marine fish production, and (f) other marine species production in Turkey

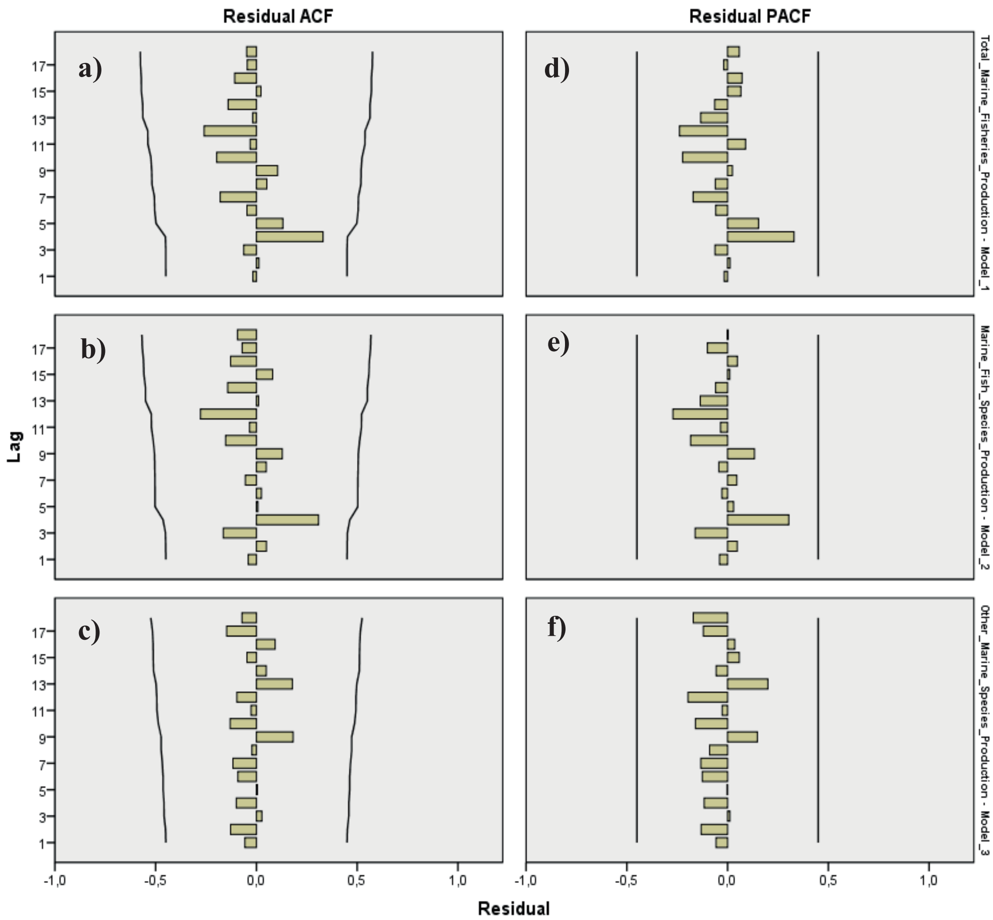

Figure 4. Residuals of autocorrelation functions of ARIMA (1,0,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production; residuals of partial autocorrelation functions of ARIMA (0,1,1) model for (d) total marine fisheries production, (e) marine fish production, and (f) other marine species production in Turkey

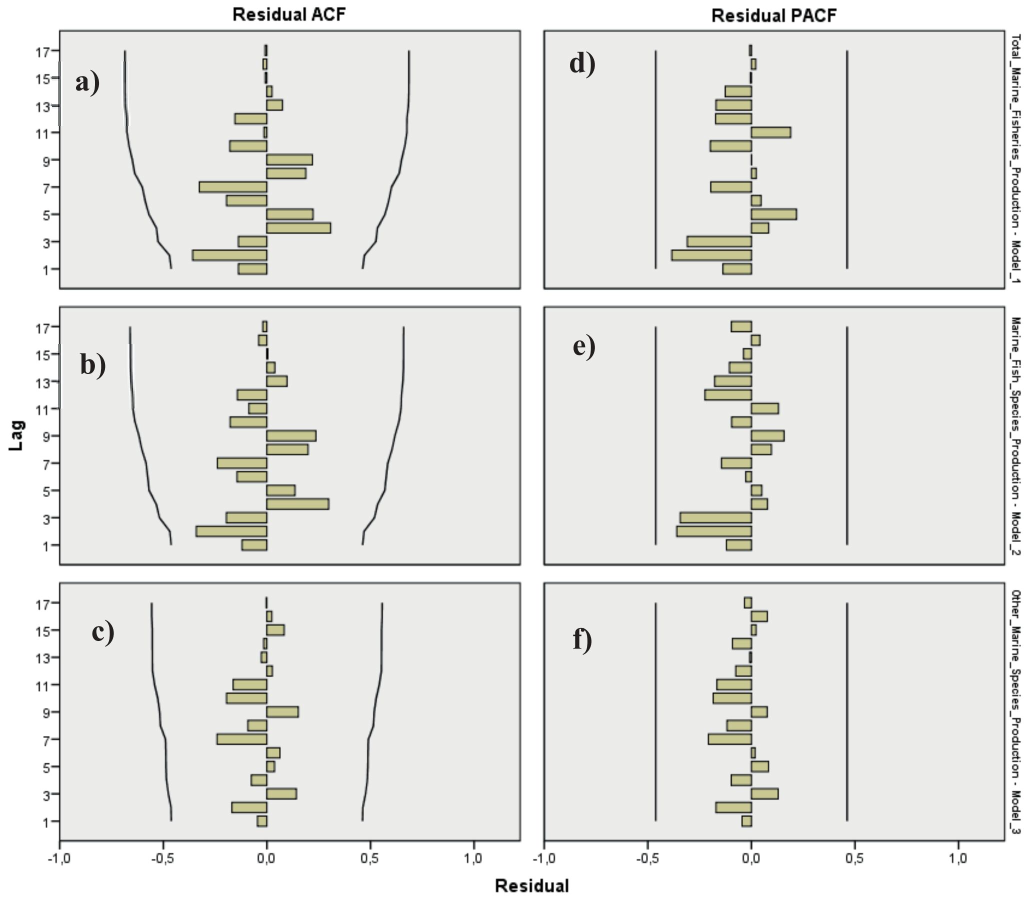

Figure 5. Residuals of autocorrelation functions of ARIMA (1,1,0) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production; residuals of partial autocorrelation functions of ARIMA (0,1,1) model for (d) total marine fisheries production, (e) marine fish production, and (f) other marine species production in Turkey

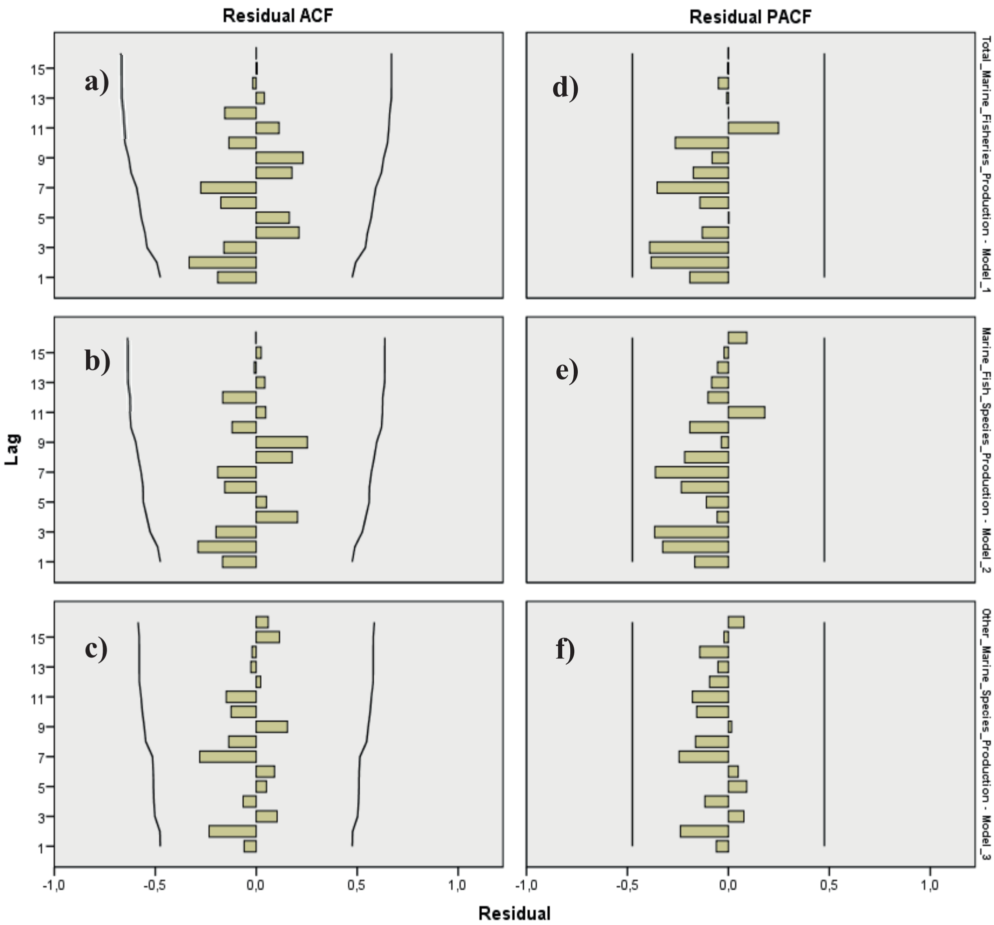

Figure 6. Residuals of autocorrelation functions of ARIMA (1,2,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production; residuals of partial autocorrelation functions of ARIMA (0,1,1) model for (d) total marine fisheries production, (e) marine fish production, and (f) other marine species production in Turkey

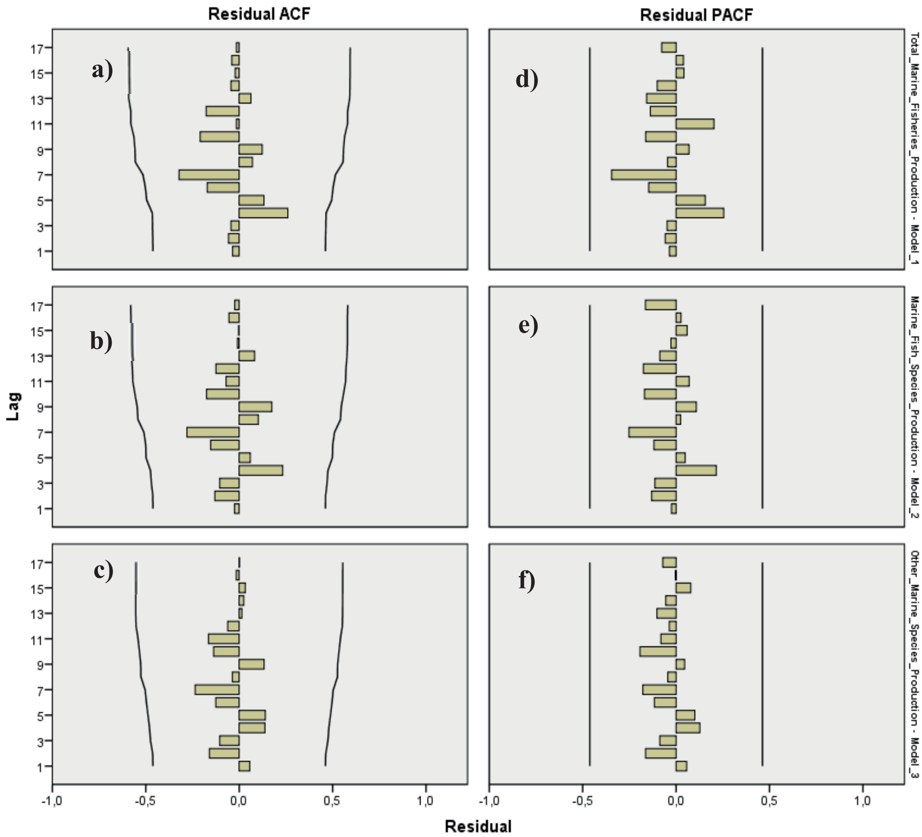

Figure 7. Residuals of autocorrelation functions of ARIMA (2,1,2) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production; residuals of partial autocorrelation functions of ARIMA (0,1,1) model for (d) total marine fisheries production, (e) marine fish production, and (f) other marine species production in Turkey

Natural logarithm transformation was performed to the time series dataset before time series modelling and forecasting with ARIMA models. Time series plots and future forecasts of ARIMA (0,1,1), ARIMA (1,1,1), ARIMA (1,0,1), ARIMA (1,1,0), ARIMA (1,2,1), and ARIMA (2,1,2) models were demonstrated in Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, and Figure 13, correspondingly. Lower confidence limits, upper confidence limits, observed values, and fit values were also illustrated in figures. All ARIMA models (except the ARIMA (1,0,1) model) predicted decreasing trend in the marine fisheries production amount (Figure 8a, Figure 9a, Figure 11a, Figure 12a, Figure 13a) similar to marine fish production amount (Figure 8b, Figure 9b, Figure 11b, Figure 12b, Figure 13b). On the other hand, all ARIMA models (except the ARIMA (1,0,1) model) predicted increasing trend for other marine species production in Turkey (Figure 8c, Figure 9c, Figure 11c, Figure 12c, Figure 13c). ARIMA (1,0,1) model forecasted contrary trends according to other ARIMA models (Figure 10a, Figure 10b).

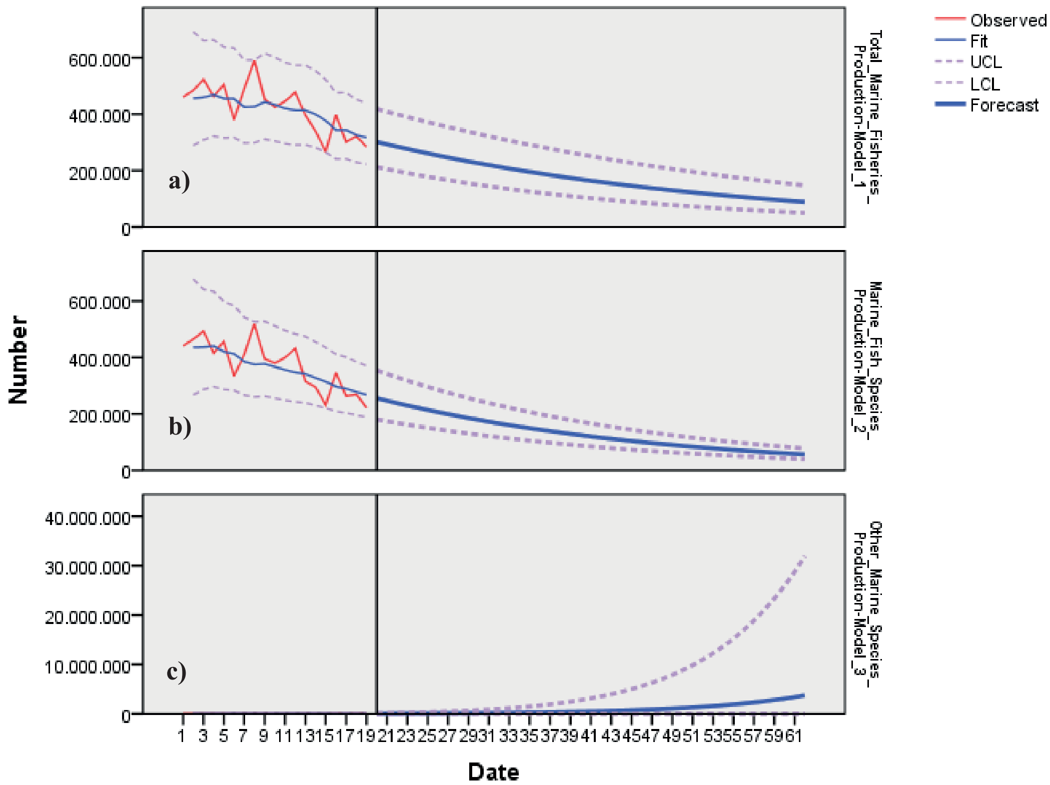

Figure 8. Outputs of ARIMA (0,1,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

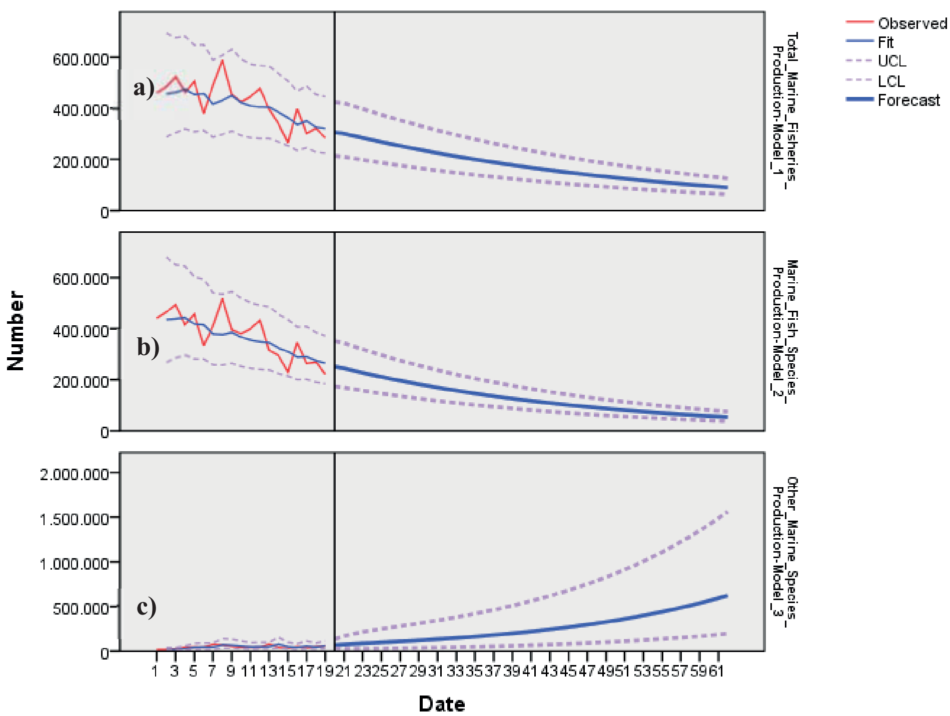

Figure 9. Outputs of ARIMA (1,1,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

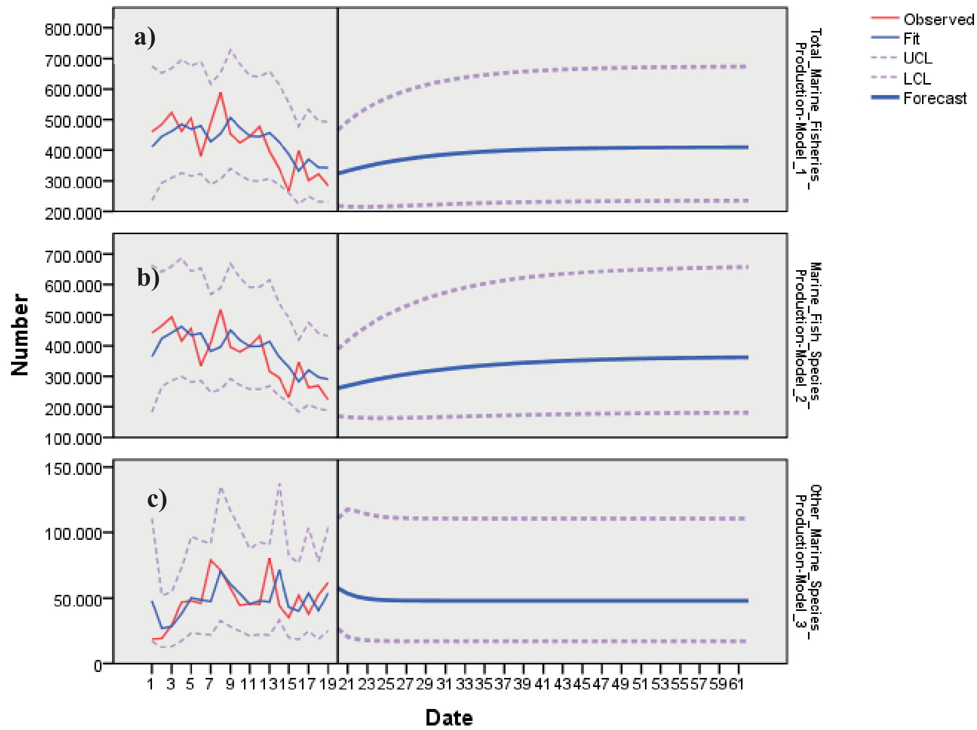

Figure 10. Outputs of ARIMA (1,0,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

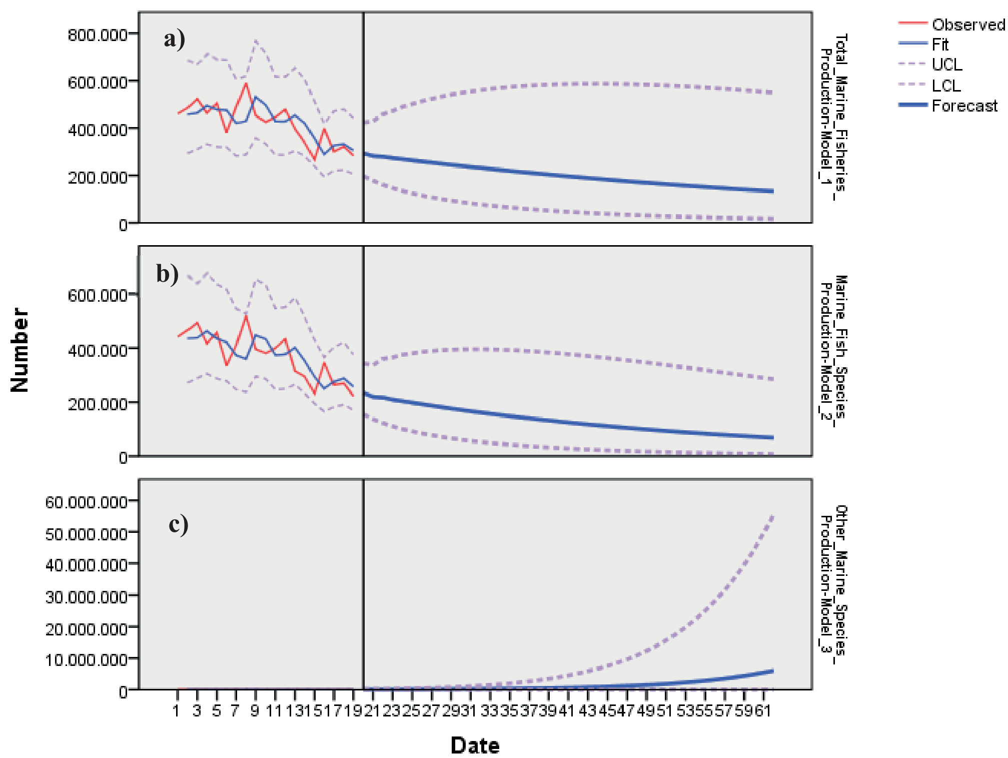

Figure 11. Outputs of ARIMA (1,1,0) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

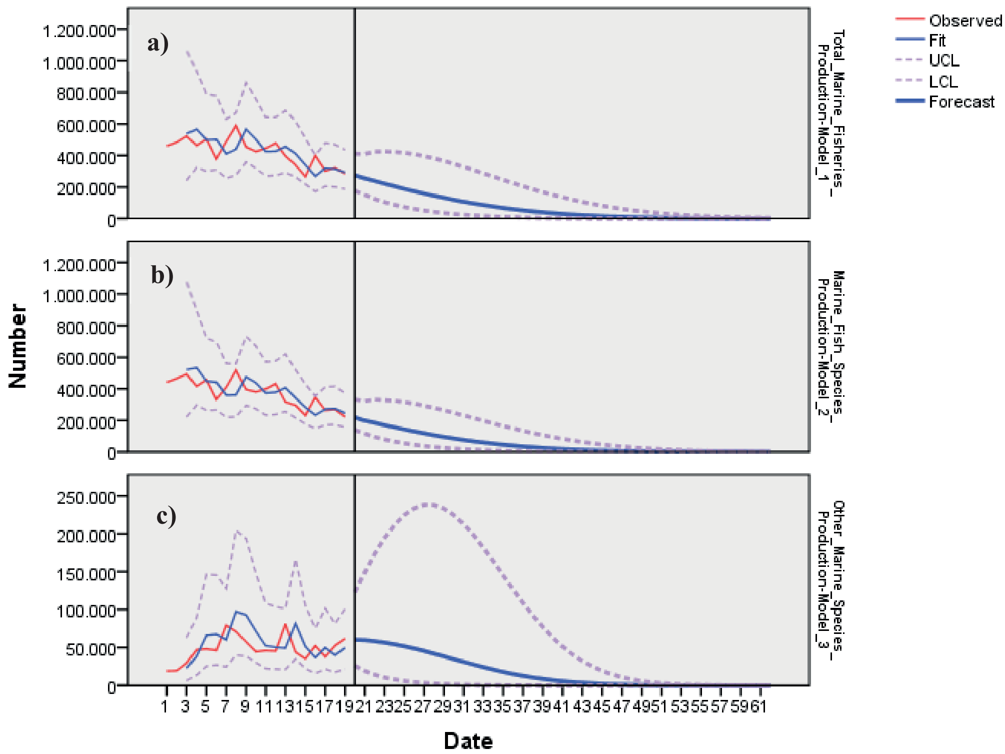

Figure 12. Outputs of ARIMA (1,2,1) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

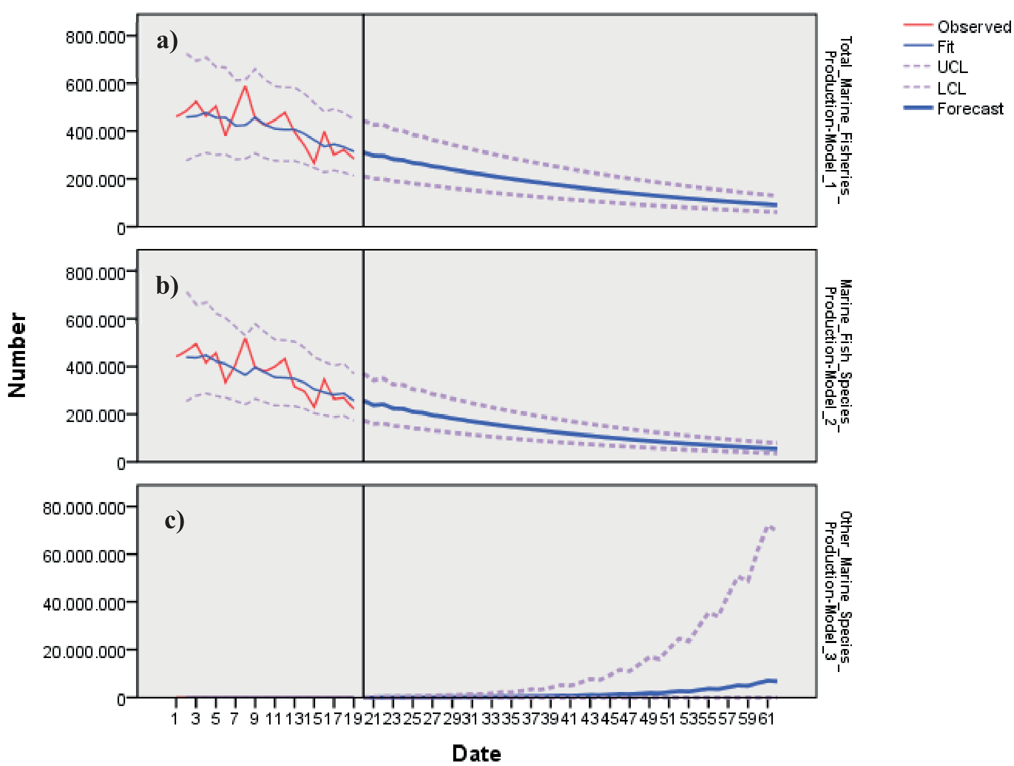

Figure 13. Outputs of ARIMA (2,1,2) model for (a) total marine fisheries production, (b) marine fish production, and (c) other marine species production in Turkey

The best fitted model is the model over and done with random residuals at a certain significance level. Thus, the significance levels of ARIMA models were compared. Furthermore, Ljung-Box test statistic was accomplished to agree the randomness. However, Ljung-Box test statistics could not be calculated except the ARIMA (1,0,1) model, as it probably has fewer input variables in the dataset. Normalized Bayesian Information Criterion (BIC), R-squared and p-values were considered to select the best fitted model. The values of p and R-squared that nearby zero and lower values of normalized BIC specify a good fit. The accuracy of models was assessed by using commonly used performance measures which are mean absolute error (MAE), root mean square error (RMSE), and mean absolute percentage error (MAPE) (Table 3). RMSE is a respectable measure of how precisely the model forecasts the response, and if the core aim of the model is forecast, RMSE is the most imperative criterion for fitting (Grace-Martin, 2020). Low RMSE values show better fit. Consequently, ARIMA (0,1,1) model was selected the best fitting model to predict the future trends of the marine fisheries production in Turkey.

Table 3. Parameters of ARIMA models for predicting of marine fisheries production in Turkey

Parameters	ARIMA (0,1,1)	ARIMA (1,1,1)		ARIMA (1,0,1)		ARIMA (1,1,0)	ARIMA (1,2,1)		ARIMA (2,1,2)			
	MA	AR	MA	AR	MA	AR	AR	MA	AR		MA	
									Lag1	Lag2	Lag1	Lag2
Coefficient	0.810	0.143	0.996	0.890	0.453	-0.431	-0.394	0.976	-0.585	0.161	0.275	0.720
SE of coefficient	0.213	0.340	9.106	0.249	0.401	0.225	0.272	2.567	3.202	0.4486	16.974	11.671
p-value	0.002	0.679	0.914	0.003	0.275	0.073	0.169	0.710	0.858	0.746	0.987	0.952
Normalized BIC	22.524	22.729		22.872		22.776	23.263		23.199			
R^2	0.488	0.498		0.379		0.341	0.189		0.495			
RMSE	66265.226	67769.674		73404.902		75155.925	87688.309		72983.738			
MAPE	12.043	11.921		15.109		14.612	15.689		11.824			
MAE	48723.266	48614.031		59004.071		60132.399	23.263		48458.595			
Ljung-Box Statistics	-	-		15.318		-	-		-			
Ljung-Box *p*-value	-	-		0.502		-	-		-			

4. Discussion

Gephart *et al.* (2017) highlighted that food from marine resources has a worldwide significance for nutrition of people and seafood is the most traded food commodity. Unforeseen dilemmas or shockwaves to production of food could have destructively impacts on the trade and price of food commodities. The patterns and trends of these shocks to fisheries and aquaculture are poorly deliberated. Thus, it confines the ability to simplify or estimate responses to environmental, political, and economic alterations.

Several methods used for the predicting trends in any time series. A frequently used Spearman's rho and Mann-Kendall tests have some restrictive assumptions. These restrictive assumptions were indicated by Kişi (2015) as the status of normal or abnormal distribution, the length of the data, and independent structure of the time series. Trend analysis was frequently used to understand and predict the future trends in hydrometeorological time series by numerous researchers (Kale *et al.*, 2016a; Kale *et al.*, 2016b; Kale *et al.*, 2018; Ejder *et al.*, 2016a; Ejder *et al.*, 2016b; Kale, 2017a; Kale, 2017b; Kale and Sönmez, 2018a; Kale and Sönmez, 2018b; Kale and Sönmez, 2019a; Kale and Sönmez, 2019b; Kale and Sönmez, 2019c; Sönmez and Kale, 2020, Arslan *et al.*, 2020). In addition, Şen's innovative trend analysis methodology was repeatedly performed to determine the trends in hydroclimatological time series (Şen, 2014; Şen, 2015; Kişi *et al.*, 2015; Gedefaw *et al.*, 2018; Alifujiang *et al.*, 2020).

Various studies examined the latest trends in production of fisheries resources in global scale. Srivastava (2004) studied the trends in production and export of fish in India. The author documented that fish production in marine and inland waters in India significantly raised over the time. Besides, the author directed that the relatively higher growth of inland fish production call attention to that aquaculture is being considered as the occupation for avocation making and promising revenue for local people. Karimpour *et al.* (2011) explored the status of freshwater crayfish in Iran. Oladimeji (2017) studied the trend in fish production and total expected demand in Nigeria between 1970 and 2014. The authors specified that expected demand for fish grow faster than difference in local fish production. Likewise, Oladimeji (2018) investigated the trend in artisanal fisheries production in Nigeria and it was documented that the demand for fish products of Nigeria gradually improved during the study period like gross domestic product of Nigeria, although the domestic fish commodity production and other agricultural harvests differs. Furthermore, the author states that no relationship was found between either aquaculture or artisanal fisheries production and economic growth from 1970 to 2014.

In Turkey, there is no published paper on the current status and forecasting of the future trends of marine fisheries production although several studies were published on the current status of the freshwater crayfish (Harlıoğlu and Harlıoğlu, 2009; Türel *et al.*, 2015; Cilbiz *et al.*, 2020; Berber, 2020). Additionally, Berber *et al.* (2014) indicated problems and solutions for making certain the sustainability of freshwater crayfish stocks with regards to fisheries management. On the other hand, there are restricted papers on the assessment of fisheries production of some provinces in Turkey. For instance, inland fisheries production of Kocaeli province was investigated by Saygı and Bayhan (2015). In addition, fisheries activities in coastal areas of Bursa and Kocaeli provinces were studied and socio-economic analysis was performed by Düz (2011). Özyalın (2016) provided an overview to fish production of Yozgat city in Turkey. However, Yozgat has no coastal area to marine waters. Its fishery production can only include the fish production in inland waters such as rivers, lakes (natural or artificial), and reservoirs. The fish production is carried out by inland fishing activities and aquaculture in Yozgat city. Kale (2019) assessed the trends in the inland fisheries production of Çanakkale province. The author reported that the inland fisheries production amount was decreasing year-by-year.

There is no study for evaluating the patterns and forecasting the future trends in marine fisheries production in Turkey. The present paper is the first study on the future estimating and the assessment of the trends in the marine fisheries production in Turkey. Marine fisheries resources should be improved by ensuring the sustainability of stocks. Marine fisheries production can raise the income level for the local fishers or relevant people. In addition, the increase in the production of marine fisheries can contribute to the social welfare and economic growth by providing commercial or business opportunities for subsequent sectors. Fisheries management application must be implemented to maintain the sustainable use of marine fisheries resources by considering ecosystem approach to fisheries management and right-based fisheries management. The future of the marine fisheries is depending on the development of stronger fisheries management strategies (Kale, 2019). Decision-makers should make efficient and appropriate management strategies and policies to prevent potential negative impacts of climate change, overexploitation, marine pollution, illegal fishery activities.

Conclusion

In conclusion, this paper evaluated the trends in the marine fisheries production in Turkey. Furthermore, various trend analysis methodologies and forecasting models were compared to forecast the future trends in marine fisheries production. The results of the innovative trend analysis methodology and ARIMA models revealed that marine fisheries production has a decreasing trend between 2000 and 2018 even though there are some rises and falls. ARIMA models predicted that the marine fisheries production has a tendency to decrease in the future period. Numerous dynamics such as overexploitation, climate change, code of practice, and fisheries management strategies have impact on the amount of marine fisheries production. Therefore, suitable strategies for fisheries management and codes of conduct should be scheduled and executed to develop the production.

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