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Original Article

Modelling the time series of capture fishery and aquaculture production in Iran

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Abstract: The trend of capture fishery and aquaculture production in Iran shows an ascending trend. An estimate of future production may be useful for management purposes and to provide some clues about the effectiveness of the current plans to reach the goals. We used the data provided by the Food and Agricultural Organization of the United Nation (FAO) to model the time series of the production of aquatics in both sectors. The data covered the years 1980-2018. We predicted the production of aquatics until 2025 using autoregressive integrated moving average models. Several techniques were used to estimate the parameters of the model. However, searching the all possible values of the parameters provided the model with the best predictability. According to the selected model, the production of capture fishery will have an ascending trend and increase to 1,513,533 tons in 2025. Aquaculture production will also have an increasing trend, however, the rate of change will be lower than that of the capture fishery. Aquaculture production will reach to 552944 tons in 2025. The forecast is based on the assumption that the rate of changes in the development of capture fishery and aquaculture will remain in the present status. Sudden changes in management practice or environmental conditions may have a remarkable influence on future production.

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Introduction

The Caspian Sea in the north, and the Persian Gulf and Oman Sea in the south have provided a unique status for the Iran in terms of fisheries, transport and trade. The Caspian Sea is the habitat of many precious sturgeon fishes though their present status is not promising. The indigenous fish fauna of the Caspian Sea basin comprises 159 species with 62% are considered endemic to the basin (Naseka and Bogutskaya, 2009; Esmaeili et al., 2018) indicating the importance of this Sea in terms of species diversity. The capture fishery is one of the main economic activities of the southern Caspian Sea that many people in the region is relied on. Nowadays, cage culture, along with capture fishery, is being practised in this water body providing additional job opportunity for the locals and is gradually taking an important place in the production of fishery products. The catch in the Caspian Sea has decreased from 98000 in 2000 to 44279 tons in 2009 indicating a 54% decrease in the total catch (Iranian Fishery Organization, 2010). Despite the invaluable importance of the Caspian Sea, it is being suffered from pollution, overfishing, and ballast water problems (Eagderi et al., 2013). The ecological problems of the Sea will threaten the long term sustainable fisheries and subsequently the living status of the locals residing on its coastal areas. The close cooperation of five countries around the Sea to improve the present status of the Sea is indispensable.

The Persian Gulf is a shallow semi-enclosed water and is connected to the Oman Sea through the Strait of Hormuz with the fishery being an important activity of the region, second only after the oil industry (Carpenter et al., 1997). Among the neighboring countries, Iran has the greatest exclusive economic zone and the longest coastline. This body of water is the living and spawning ground of many marine fishes harbouring reef ecosystems and also pearl oysters. The total fish species of Persian Gulf comprise 743

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species, of them, many are important in terms of fisheries (Eagderi et al., 2019). Several important species live in the Persian Gulf and Oman Sea including tunas and mackerels (Karimpour et al., 2013). The brittle ecosystem of the Persian Gulf has experienced several major damages by the oil wars and tanker sinking (Alavian Petroody et al., 2017). Also, overfishing, illegal and unmonitored catch by foreign fleets are among its current problems. Despite the damages incurred to the ecosystem of the Persian Gulf, the catch had an ascending trend increasing from 260500 in 2000 to 348122 tons in 2009 indicating a 33% increase in the catch.

Aquaculture is a growing industry in Iran. The major part of aquaculture production belongs to warm water fishes especially Chinese carp, and in lower stands, rainbow trout, freshwater and marine shrimp (Karimpour et al., 2013). The aquaculture production has increased from 66000 in 2000 to 207353 tons in 2009 indicating over 214% growth in this sector (Iranian Fishery Organization, 2010).

A time series a sequence of data listed in time order. Time series and the related analyses are used in various fields, including statistics, economics, earth science and engineering (Amiri et al., 2018). Modelling the time series provides a tool to forecast future values. Times series analyses have been extensively used in fishery science for forecasting the catch and landings (Stergiou et al., 1997; Koutroumanidis et al., 2006; Amiri et al., 2017, 2018). The autoregressive integrated moving average model (ARIMA) is one of the widely-used time series models in fisheries forecasting studies (Stergiou, 1989; Tsitsika et al., 2007; Bako et al., 2013). The knowledge about the probable future trend of data is of high importance in management practice. The present study thus aimed to predict the future trend of capture fishery and aquaculture productions in Iran using an ARIMA model. we used several methods to estimate the parameters of the model.

Materials and Methods

All calculations were made using R 4.0.3. The data of capture fishery and aquaculture production were downloaded from the FAO website (www.fao.org) for 1980-2018. The data were transformed into time series using the function ts() with the frequency = 1, and examined for outlier using the function tsclean(). Since no outlying data were found, all data were used for modelling. The data of the first 28 years (i.e. 1980-2007), covered 70% of all data and were used as training data, the rest were used as testing data.

Model specification: The autocorrelation (ACF) and partial autocorrelation function (PACF) plots indicated some significant autocorrelation in some lags. Therefore, autoregressive integrated moving average (ARIMA) model was used for modelling and forecasting of the time series (Jebb et al., 2015). The ARIMA needs the time series to be stationary (Coghlan, 2015), that is, the mean, variance and autocorrelation of the time series should be constant. To examine the stationary of the time series the augmented Dickey-Fuller test (ADF) was used. The ADF test indicated that time series were not stationary. They had no constant variance over time, natural logarithm was thus used. Differencing was used to detrend the time series. After transformation with logarithm and differencing, the ADF test was used again to examine the stationarity of the transformed data. Non-stationary data were transformed using the Box-Cox method (Nelson and Granger, 1979) with ADF being used again.

Parameters estimation: The ARIMA model has three components: autoregressive (AR), integrated (I) and moving average (MA). The components AR and MA are the predictors explaining the autocorrelation in the time series. The integrated component indicates the differencing used to detrend the time series making it stationary. The orders of these components are shown by p, d and q. There are some methods to determine p, d and q: (1) transforming the data using natural logarithm, differencing or both, then performing ADF test to examine the stationarity of data and finding d. The ACF and PACF plots are then used to find p and q (Coghlan, 2015); (2) there is a function (auto.arima()) in the package forecast that find automatically p, d and q (Hyndman et al., 2007). It is worthy to note that the default values in the

Table 1. The analyses on time series of catch to estimate parameters of the ARIMA model.

Time series	A significant autocorrelation in time series	P value of the ADF test before data transformation	Parameter estimation method	Transformation			Parameter			P value of the ADF test after data transformation	Residual analysis					RMSE
				Natural logarithm	Differencing	Box-Cox	p	d	q		Lack of significant autocorrelation in ACF plot	Lack of significant autocorrelation in PACF plot	P value of the Shapiro-Wilk test	P values of the Ljung-Box tests at different lages > 0.05	P values of the McLeod-Li tests at different lags > 0.05	
Catch	Yes	0.933	ACF and PACF plots	Yes	Yes	No	0	1	0	0.010	Yes	Yes	< 0.001	Yes	Yes	225170.00
			auto.arima	Yes	Yes	No	0	2	1	0.010	Yes	Yes	0.001	Yes	Yes	159732.00
			Eacf	Yes	Yes	No	0	1	0	0.010	Yes	Yes	< 0.001	Yes	Yes	225170.00
			armasubsets	Yes	Yes	No	0	1	0	0.010	Yes	Yes	< 0.001	Yes	Yes	225170.00
			armasubsets	Yes	Yes	No	4	1	0	0.010	Yes	Yes	< 0.001	Yes	Yes	185287.50
			Searching all possible values	Yes	Yes	No	4	1	9	0.010	Yes	Yes	< 0.001	Yes	Yes	32230.17

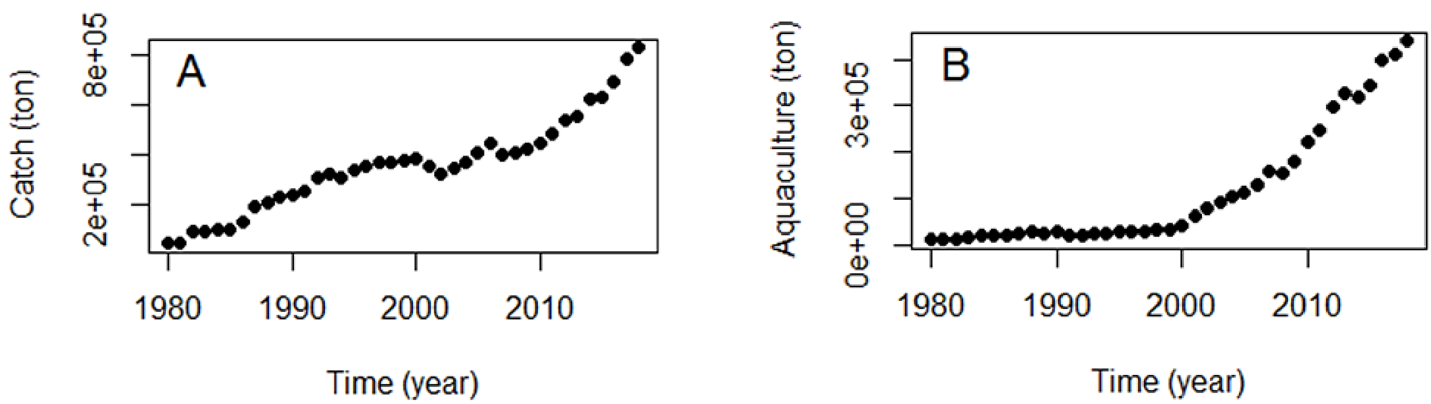

Figure 1. Temporal changes of capture fishery (A) and aquaculture production (B) in Iran during 1980-2018.

function for p, d and q are 5, 2 and 5. Therefore, these values can change if required. The method to estimate the parameters can change, too. The adequacy of the model is examined after parameter estimation using the ACF and PACF plots; (3) estimating p and q using the extended autocorrelation function (EACF) using the function eacf() from the package TSA (Cryer and Chan, 2008); (4) estimating p and q by the best ARIMA subset model using the function armasubsets() in the package TSA (Cryer and Chan, 2008). The latter method may suggest several values for p and, therefore, further investigation may be required to find the best values for p and q. The above methods were used for the estimation of an ARIMA model. To examine the adequacy of the selected model, root mean square error (RMSE) was used with the data predicted by the model and testing data. Finally, we examined all possible values of p, d and q (in the range of 0-10 and 1331 times totally) to find the model with the smallest RMSE as the best model.

Evaluating the model: The residuals of the selected model were evaluated using ACF and PACF graphs to find if all variance of the data has been explained by the model. Normality, independence and constant variance of the residuals were examined using the Shapiro-Wilk, Ljung-Box and McLeod-Li tests, respectively.

Results

Temporal changes of catch and aquaculture products: The products of capture fishery and aquaculture are shown in Figure 1. The capture from the fishing had stable ascending trend from 1980 to 2010, while the slope of the trend increased after 2010.

Table 2. The analyses on time series of aquaculture data to estimate parameters of ARIMA model.

Time series	A significant autocorrelation in time series	P value of the ADF test before data transformation	Parameter estimation method	Transformation			Parameter			P value of the ADF test after data transformation	Residual analysis					RMSE
				Natural logarithm	Differencing	Box-Cox	p	d	q		Lack of significant autocorrelation in ACF plot	Lack of significant autocorrelation in PACF plot	P value of the Shapiro-Wilk test	P values of the Ljung-Box tests at different lages > 0.05	P values of the McLeod-Li tests at different lags > 0.05	
Aquaculture	Yes	0.990	ACF and PACF plots	Yes	Yes	No	7	3	7	0.010	Yes	Yes	0.433	Yes	Yes	343929.60
			auto.arima	Yes	Yes	No	0	1	0	0.329	Yes	Yes	0.148	Yes	Yes	61523.82
			auto.arima	Yes	Yes	Yes	0	1	0	0.815	Yes	Yes	0.170	Yes	Yes	74211.00
			eacf	Yes	Yes	No	5	3	6	0.010	Yes	Yes	0.333	Yes	Yes	273927.70
			armasubsets	Yes	Yes	No	0	3	7	0.010	Yes	Yes	0.336	Yes	Yes	273927.70
			Searching all possible values	Yes	Yes	No	1	3	8	0.010	Yes	Yes	0.142	Yes	Yes	27856.05

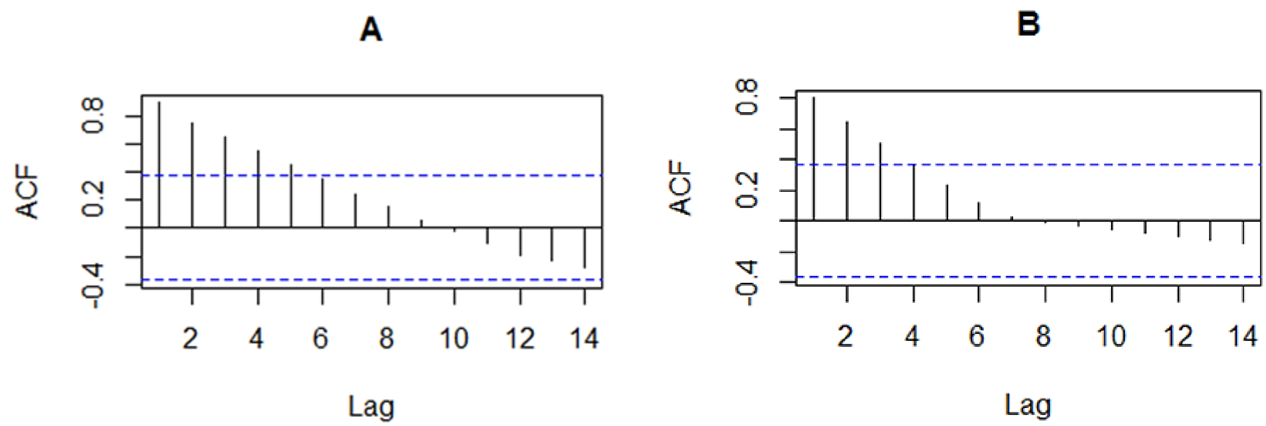

Figure 2. The ACF plot for the time series of the catch from fishing (A) and aquacultural production (B).

The product from aquaculture had gentle positive slope from 1980 to 2000 but the slope increased with greater slope until 2018 (source: www.fao.org). The ACF plot indicated significant autocorrelation in time series of capture fishery and aquaculture (Fig. 2). Hence, an ARIMA model was used.

Estimation of ARIMA model parameters: The data were analysed using various methods (Table 1). Among the various methods, searching the all possible values of p, d and q resulted in a model with the best predictability. However, the Shapiro-Wilk test rejected the null hypothesis assuming normality in the residual. Among the various methods, searching the all possible values of p, d and q resulted in a model with the best predictability for aquaculture data (Table 2).

The performance of the final model in the prediction of testing data is shown in Figure 3. The model based on searching all possible values of the parameters had the best predictability for both catch and aquaculture time series.

Prediction: The predicted values of catch and aquaculture products are depicted in Figure 4. Both catch and aquaculture are predicted to have an ascending trend. The catch will reach to over 1.5 million tons and the production of aquaculture sectors will reach to over 550000 tons in 2025.

Discussions

Estimating the future trend of production is largely helpful for fishery managers. One of the widely-used tools in forecasting the catch is the time series analysis and in particular, the ARIMA models. The present study used an ARIMA model to forecast fishery catch and aquaculture production in Iran and estimated its parameters using several methods. Of the various

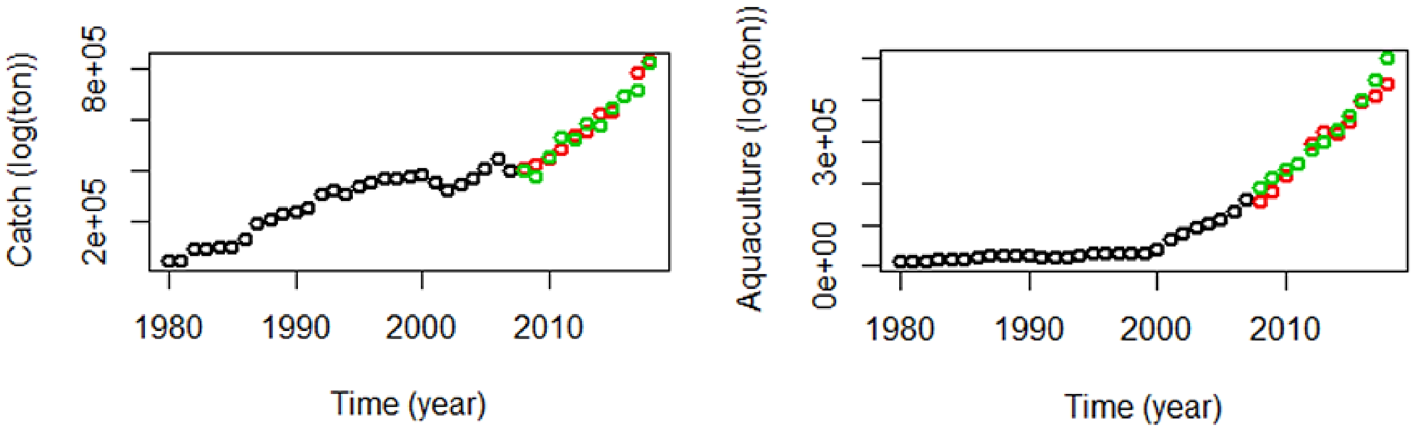

Figure 3. The performance of the final model in prediction of the testing data for time series of catch and aquaculture products. The black, red and green points indicate the training, testing and predicted data, respectively.

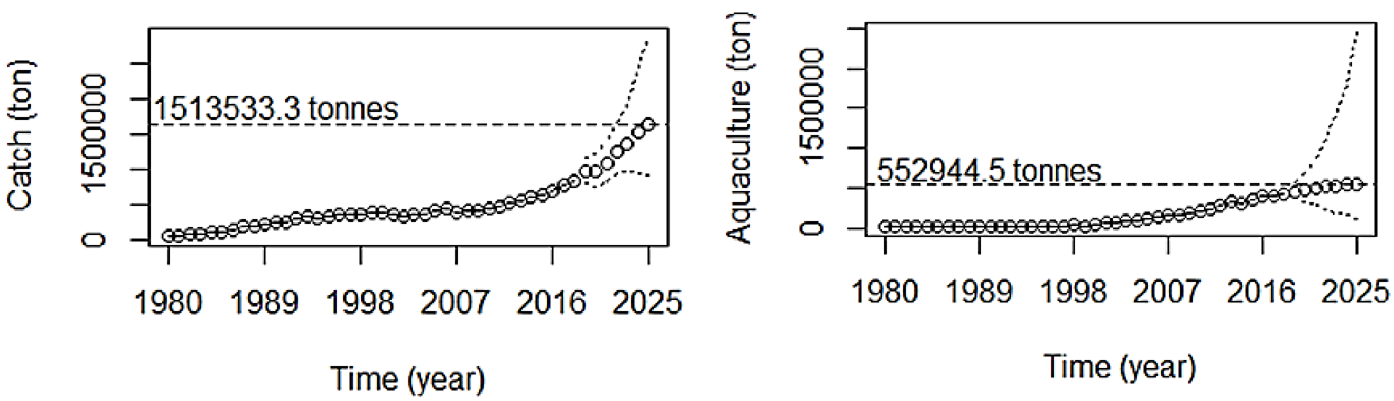

Figure 4. The prediction of aquatics production through capture fishery and aquaculture until 2025. The hollow points indicate the predicted values from 2019 to 2025. The dotted lines indicate 0.95 confidence intervals for the predicted values.

types of estimating the parameters of the ARIMA models, searching for all possible values of the parameters resulted in the best model in terms of predictability. Such a method is time-consuming, particularly, with a high number of data. Lack of this method in the literature may be related to the problem of over-fitting. Further examination of the model with a second unused series of data can further evaluate the quality of the model and investigate if the model made in this method may be over-fitted. In the present study, the number of the data was low and thus we had no chance to examine the quality of the model with a set of data in addition to those we used as testing data.

The fishery catches of Iran increased from 43659 in 1980 to 828872 tons in 2018 indicating 180% growth. However, this increase is mainly related to the latest years, i.e. after 2016. According to the model used in the present study, it is predicted a 82% increase in capture fishery of Iran in 2025 compared with 2018. While the current trend is promising, our prediction is based on the data presented to FAO. According to an overview by FAO, the Iranian marine resources seem to have reached to their biological limits (FAO, 2020). Therefore, the trend of the forecasted figure about the future capture fishery production may shift downward or remain stable. The precision of the method to gather the data is a crucial step that should always be scrutinized by the related organizations and our prediction is hence surely influenced by the quality of the data (Watson and Pauly, 2001).

The predicted increasing trend of capture fishery of Iran hints an increasing by-catch the Iranian fishing fleets may encounter in upcoming years. The by-catch has always been one of the main environmental problems of the capture fisheries. The rate of fishery by-catch may be dramatically high. For instance, 3.7 million tonnes of fish were landed in the United States while 1.06 million tonnes (~30%) of the caught fishes were discarded (Harrington et al., 2005). The by-catch in Iranian fishery depends on the target species, for example, in case shrimps, it may reach to > 86% (Farrokhi et al., 2014). Therefore, despite the promising figures for the capture fisheries, the forthcoming pressure on the Iranian marine ecosystems should be taken into account in planning for the future.

The aquaculture has had a steady growth in Iran. Based on our model, it will reach to over half a million tonnes in 2025, i.e. ~ 26% growth compared with that of 2018. Aquaculture is becoming a substitute or replacement for the capture fishery production. Aquaculture has a special place in Five-Year plans of the country and various encouragements have been granted for private sectors. With regards to the pressure on the marine sources, it seems that the forecasted growth of aquaculture is quite realistic. In conclusion, our study indicates a growth both for capture fishery and aquaculture production in Iran. Further study is recommended to forecast the production of aquatics at the species level.

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