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Mathematical Forecasting of Fish Production in India Using ARIMA Models

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ABSTRACT

Fish has an important role in the survival and health of human population. Malnutrition is a very big problem in many countries. And fish plays an important role in resisting malnutrition. Thus, fish referred as rich food for poor people as fish provide essential nutrients, mainly quality proteins and fats (macro nutrients) vitamins and minerals (micro nutrients). Because it is a unique source of several vital nutrients, including omega-3, vitamin A, vitamin B12, vitamin D, polyunsaturated fatty acids, zinc, iron, and calcium, among others, fish is a terrific way to maintain our bodies healthy. Fish is important to our nation's economic growth as well. After China, India ranked second in terms of fish production. Given that they contribute more than 5% of the agricultural GDP, fisheries are a significant sector of the Indian economy. Fish oil, fish flesh, fertiliser, fish glue, and other important goods can all be produced from fish. Here, we're attempting to use ARIMA models to forecast India's marine and overall fish production. The main objective of our study is to provide idea about Opportunities and Challenges for Entrepreneurship in this field. The Ministry of Agriculture and Farmers Welfare, Government of India, provided the data for this study. India's total fish production rose from 2306 thousand tonnes to 12606 thousand tonnes between 1978 and 2018, while the country's marine fish production went from 1490 thousand tonnes to 3688. According to this study, the best-fitting models for marine and total fish output in India were ARIMA (0, 2, 1) and ARIMA (0, 2, 1).

1. **Introduction:** The growing human population has led to a major increase in the need for food production. The health and survival of the human population are significantly influenced by fish. A major issue in many nations is malnutrition. Additionally, eating fish helps prevent malnutrition. Because fish supply important elements, namely high-quality proteins and fats (macronutrients) and vitamins and minerals (micronutrients), they are commonly referred to be rich food for the impoverished. Because it is a unique source of several vital nutrients, including omega-3, vitamin A, vitamin B12, vitamin D, polyunsaturated fatty acids, zinc, iron, and calcium, we can maintain our health by eating fish. The Indian fisheries industry employs more than 14.5 million people at the primary level and many more along the value chain (ICAR-
Central Institute of Freshwater Aquaculture & Ss, 2017). The impact of mangroves is crucial for raising fish production in India. Both the technical efficiency of fish production and commercial fish production benefit from it (Anneboina & Kavi Kumar, 2017). Due to its extreme diversity, India, a tropical nation, has over 2.02 million square kilometres of exclusive economic zone (Sathianandan, n.d.). Despite this improvement, India continues to lag behind other maritime nations in its use of fish and aquatic resources for protein and nutritional security (Barik, 2017).

In order to satisfy India's future demand for fish, the output prediction is crucial. A total of 12605 thousand tonnes of fish were produced in India in 2017–18, up from 2306 thousand tonnes in 1950–51, while the output of marine fish climbed from 5149 thousand tonnes in 1950–51 to 3688 thousand tonnes in 2017–18. Of India's total fish production in 1950–51, inland fish production made up 71.11% and marine fish production 28.98%. However, in 2017–18, inland fish production made up 70.73% of the nation's total fish production, while marine fish production made up 29.26%. Fish production grew at an average rate of 10.14 percent in 2017– 18 compared to 2016–17.

Gujarat is the largest producer of marine fish in India, while Andhra Pradesh is the largest producer of inland fish. For scientists and managers involved in fisheries management, time series modelling is a crucial tool (Mah et al., 2018). When estimating the significance of any variable, the Autoregressive Integrated Moving Average (ARIMA) technique outperforms Regression Analysis (Anuja et al., 2017). In his article, Borkar (2017) used ARIMA models to forecast and simulate India's inland and marine fish production. In his conclusion, he proposed that the ARIMA (0, 1, 0) model was suitable for India's inland and maritime food production. The ARIMA model is also used by Yadav et al.

(2020) to predict fish production in Assam, India. They discovered that ARIMA (1, 1, 0) was the most effective model for predicting Assamese fish production. Similar research utilising Seasonal ARIMA models to predict fish production in Odisha, India, has been conducted by Raman et al. (2017). Moreover, Raman et al. (2018) forecasted fish production in Chilika lagoon, Odisha, India, using the Time Series forecasting model.

In light of this, an effort was made to use ARIMA models to anticipate India's marine and total fish production as well as analyse the growing trend. Entrepreneurs will benefit from this study's analysis and examination of the opportunities and challenges in this industry.

2. Data and Methodology:

The Ministry of Agriculture and Farmers Welfare, Government of India, provided the secondary data used in this study. Data on India's total fish production and marine fish production were gathered during a 40-year period, from 1978–1979 to 2017–2018, and are publicly accessible.

Here Box-Jenkins (ARIMA) model is used. In the early 1970s, George Box and Gwilym Jenkins created it. This technique is frequently used in disciplines like economics, finance, and engineering to forecast future values since it works especially well for both stationary and non-stationary time series.

Time series:

A time series is a set of data, gathered or listed in time order, where the time interval is consistent. Mathematically, the common notation is,

$$y = f(t), w ----------(i)$$

$$here\ y\ is\ the\ value\ of\ the\ variable\ at\ time\ t.$$

Jarque – Bera test:

This is a test of goodness – of – fit, whether the dataset is normally distributed or not. Here the test statistic is non – negative and if it is far from zero, then it indicates non- normality of the dataset.

The test statistic is,

$$JB = \frac{n}{6}(S^2 + \frac{1}{4}(K-3)^3) ----------(ii)$$

Where n is the degrees of freedom, S is the sample skewness, K is the sample kurtosis.

Structural breakpoints:

Structural breaks mean if there any potential change in the time series data. Thus, for any potential change in time series data an F–statistic (Chow test statistic) is calculated. The null hypothesis for the test is

$$H_0 : There\ is\ not\ any\ structural\ change\ in\ the\ dataset$$

$$H_1 : There\ is\ not\ any\ structural\ change\ in\ the\ dataset$$

For this an OLS (Ordinary Least Square) model is fitted for the observations, the test statistic is

$$F = \frac{RSS - ESS}{ESS * (n - 2 * k)} \text{---------------} (iii)$$

Where, there are 2k estimated parameters, ESS define error sums of square, RSS is computed restricted sums of squares.

Autoregressive Integrated Moving Average (ARIMA) model:

The Auto Regressive Integrated Moving Average model is known as ARIMA. It is a widely used statistical technique for forecasting time series. Three parts make up the model: AR (Auto Regressive) → Forecasts future values based on historical data. To render the series stationary, I (Integrated) → Differencing. MA (Moving Average) → Improves forecasts by using historical forecast errors. If the time series y_t is stationary after the d^{th} difference, it follows the Autoregressive Integrated Moving Average (ARIMA) model.

The Non – seasonal ARIMA models ARIMA (p, d, q), where autoregressive term count denoted by 'p', to make the series stationary, 'd' is the number of differencing operations and 'q' is the number of terms in the moving average. Here p, d and q are non-negative.

If y denotes the d^{th} difference of Y, then if

d= 0, $y_t = Y_t$

d = 1, $y_t = Y_t - Y_{t-1}$

d =2, $y_t = (Y_t - Y_{t-1}) - (_{t-1} - Y_{t-2})$

The general ARIMA (p, d, q) model can be presented as,

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \varepsilon_t + \varphi_1 \varepsilon_{t-1} + \varphi_2 \varepsilon_{t-2} + \ldots + \varphi_q \varepsilon_{t-q} \ldots\ldots (iv)$$

Were, predicted

$$Y_t = constant + linear\ combination\ of\ lags\ of\ Y\ (upto\ lag\ p)$$

$$+ linear\ combination\ of\ lagged\ forecast\ errors(\ upto\ q\ lags)$$

The estimation of ARIMA model was first approached by Box and Jenkins (1976).

Model specification:

This phase shows that the methods for figuring out the values of p, d, and q have been applied. The autocorrelation and partial autocorrelation functions are used to calculate these values. Regardless of whether the information being used is stationary, the non-zero interruptions of sample ACF and PACF are taken as the p and q parameters, and d is determined by the numbers of differentiation. Poor projections result from poor decisions about p, d, and q (Tebbs, 2010).

Auto correlation function (ACF) and Partial autocorrelation function (PACF):

Data points in a time series are connected to and averaged against the data points that came before them, according to the autocorrelation function (ACF).

The measurements $Y_1, Y_2, . . . , Y_n$ at time $X_1, X_2, . . . , X_n$, the lag k autocorrelation function is

$$r_k = \frac{\sum_{i=1}^{n-k}(Y_i-\bar{Y})(Y_{i+k}-\bar{Y})}{\sum_{i=1}^{n}(Y_i-\bar{Y})^2} \quad \text{............ (v)}$$

A stationary time series with its own lagged values can be partially correlated using the Partial Autocorrelation Function (PACF). When analysing an autoregressive model to determine the degree of lag, the function is crucial.

Augmented – Dickey Fuller test:

When examining a time series dataset for stationarity, the Augmented Dickey-Fuller (ADF) method is employed. By including the series' lag differences to account for autocorrelation, it is an expansion of the Dickey-Fuller test.

$$\Delta y_t = \alpha + \beta y_t + \varphi y_{t-1} + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} + . . . + \gamma_k \Delta y_{t-k} + \varepsilon_t ----(vi)$$

Where, α is a constant, β is the coefficient on a time trend and p is the lag order of the autoregressive process, ε_t is the error part

And, $\Delta y_t = y_t - y_{t-1}$

The unit root test is then carried out under the null hypothesis

$$H_0 : The\ dataset\ is\ not\ stationary$$

$$H_1 : The\ dataset\ is\ stationary$$

The test statistic is

$$DF_t = \frac{\hat{\varphi}}{S.E.(\hat{\varphi})} ------------------(vii)$$

The calculated value is contrasted with the pertinent Dickey-Fuller test critical value. The statistic from the ADF test is negative. Stronger rejection of the hypothesis is indicated by a test statistic with a greater negative value.

Diagnostic checking:

Our primary goal is to choose the best model from all of the models that have been identified. Models with the highest log likelihood and the lowest Akaike Information Criterion (AIC) are taken into consideration for this.

$$AIC = -2In\ L + 2k -----------------------(viii)$$

where k=p+q is the number of parameters in the ARIMA model and In L is the natural logarithm of an estimated likelihood. Better model fit is indicated by a smaller AIC score (Tebbs, 2010).

Forecast accuracy measure:

Root mean square error (RMSE): It squares the deviations and is an absolute error measure.

$$RMSE = \sqrt{\frac{\sum_{i=1} (Predicted_i - Actual_i)^2}{N}} ------------------(ix)$$

Mean absolute error (MAE): It doesn't necessitate square root or square computation.

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |x_i - m| -----------------(x)$$

Mean absolute percentage error (MAPE): The relative error metric known as mean absolute percentage error (MAPE) makes use of absolute numbers.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n} \left|\frac{Actual_i - Predicted_i}{Actual}\right| -----------------(xi)$$

3. Results and Analysis:

Table 1 displays the descriptive statistics for both data sets.

Table 1: descriptive statistics of inland and marine fish production

Measurements	**Marine fish**	**Total fish**
Min. Observation	1427	2306
Max. Observation	3688	12606

Q_1	1792.6	3105.7
Q_2	2999.5	7250.2
Mean	2592.5	5713.1
Median	2797	5368
SE Mean	111.69	438.8
LCL Mean	2367.13	4825.7
UCL Mean	2818.7	6600.3
S.D.	706.4	2775.9
Sk	-0.23	0.10
Kurtosis	-1.23	-0.10

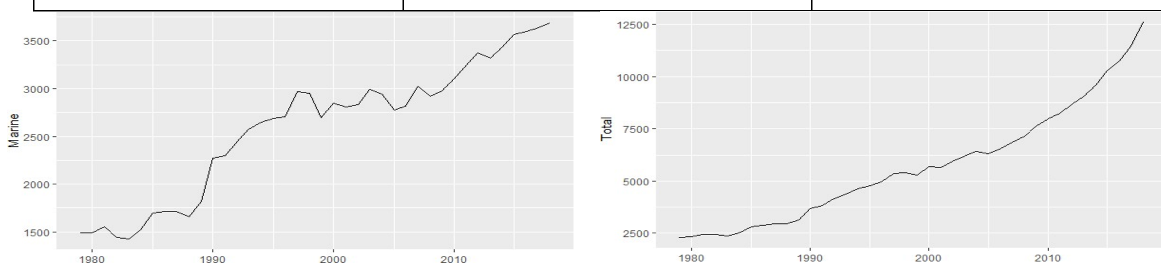
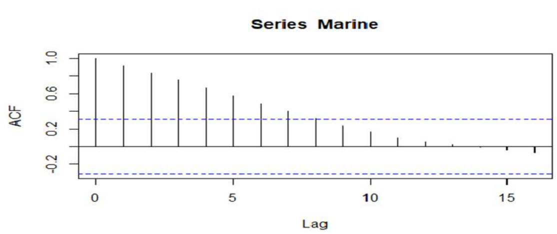


Fig1: Time series plot of Marine and Total fish production in India from the year 1978-2018



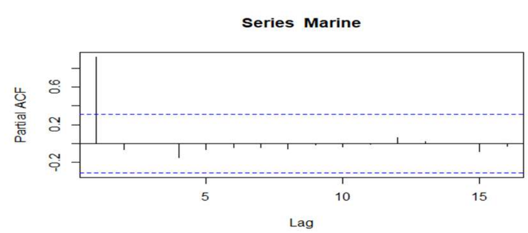
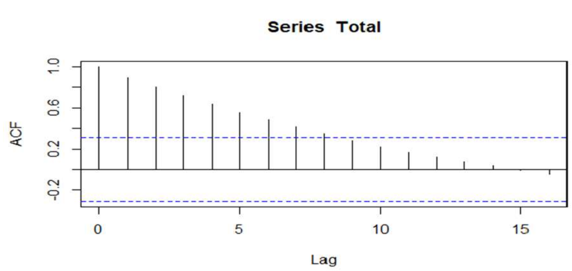


Fig2: ACF (Marine fish production)

Fig3: PACF (Marine fish production)



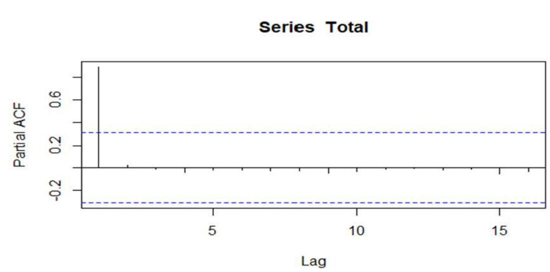
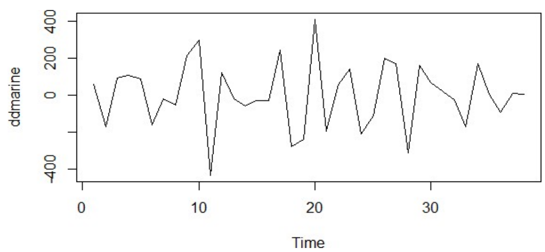
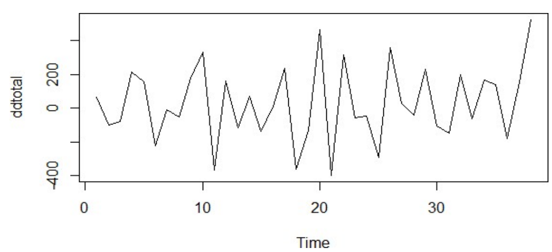


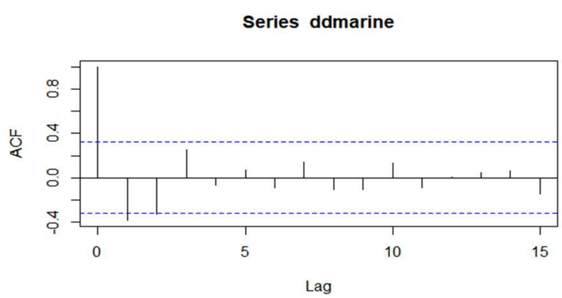
Fig4: ACF (Total fish production)

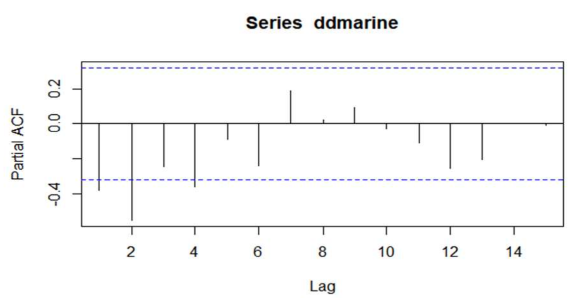
Fig5: PACF (Total fish production)

Figure 1 plots the original marine and total fish production statistics used for modelling in India. Here, we identified the data set's structural breakpoints using the F-test. The Jarque Bera test is used to determine whether the data set is typical. In our study we have used R-Programming software to see the structural breakpoints and found four structural breakpoints for marine fish data and five structural breakpoints for total fish production data. We verify the ACF and PACF of the provided data set in the model definition. Figures two and three display the autocorrelation function (ACF) and partial autocorrelation function (PACF) of marine fish production, respectively. Figures 4 and 5 also display the total amount of fish produced.









.**Fig6:** 2nd difference of the marine fish data **Fig7:** 2nd difference of the total fish data.

Fig8: ACF (2nd differencing of the marine data) **Fig9:** PACF (2nd difference of the Total data)

A minor decrease in the production of marine fish and a slight increase in the total production of fish are the results of the first difference between the two data series. In order to verify stationarity, we also employed the Augmented Dickey-Fuller test. The results showed that the p- value was greater than 0.05, which means that the null hypothesis cannot be rejected, meaning that the first difference is still non-stationary. We distinguish the data once more in order to make it stationary. Figures 6 and 7 exhibit the second difference of the two data series. Additionally, Figs. 8 and 9 depict the ACF of the second difference of the two testing data. These graphs demonstrate that the second difference between the two testing data series exhibits stationary behaviour.

Additionally, we statistically verify the stationarity of the second differenced data using the Augmented Dickey-Fuller test. Additionally, we discovered that both data series had p-values less than 0.05, which means that the null hypothesis—that is, that the second difference between the two data series is stationary—is rejected.

Model Selection and Parameter Estimation: Following differencing, the data sets became stationary. Next, we propose a few likely models for additional research. ARIMA (1, 2, 0), ARIMA (0, 2, 1), ARIMA (1, 2, 1), ARIMA (2, 2, 0), and ARIMA (0, 2, 2) are the models that have been suggested for marine fish production in India. ARIMA (0, 2, 1), ARIMA (1, 2, 0), ARIMA (1, 2, 1), ARIMA (0, 2, 2), and ARIMA (2, 2, 0) are the models that have been suggested for the entire fish production in India. Tables 4 and 5 display the suggested ARIMA models for both series together with the associated Standard errors (S. E.), Z-values, and p- Values. Table 2 displays the fitted ARIMA models' AIC and Log-Likelihood for the production of marine fish.

Likewise, Table 3 displays the AIC and Log-Likelihood of the fitted ARIMA models for total fish output. Table 2 shows that, in comparison to other fitted models for marine fish production series, Model-2: ARIMA (0, 2, 1) has a marginally lower AIC value. Additionally, Table 3 shows that Model-2: ARIMA (0, 2, 1) has a little lower AIC value than other fitted models for the total fish production series. Therefore, we forecasted the data using these two models.

Table 2: AIC and Log Likelihood of the ARIMA models of marine fish production.

Model	**ARIMA order**	**AIC**	**Log Likelihood**
1	ARIMA(1, 2, 0)	498.4	-245.5
2	ARIMA(0, 2, 1)	479.5	-237.7
3	ARIMA(1, 2, 1)	482.5	-234.7
4	ARIMA(2, 2, 0)	486.3	-245.9
5	ARIMA(0, 2, 2)	480.5	-236.7

Table 3: AIC and Log Likelihood of the ARIMA models of Total fish production.

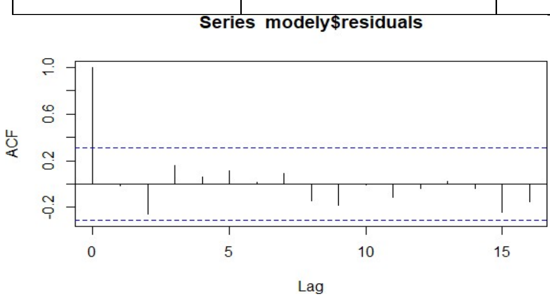
Model	**ARIMA order**	**AIC**	**Log Likelihood**
1	ARIMA(0, 2, 1)	516.3	253.1
2	ARIMA(1, 2, 0)	515.3	-257.5
3	ARIMA(1, 2, 1)	516.7	-253.3
4	ARIMA(0, 2, 2)	512.5	-254.87
5	ARIMA(2, 2, 0)	511.7	-263.9

Table 4: Parameter estimation of the ARIMA (0, 1, 1) model for Inland Fish Production.

Coefficients	Estimates	Std. Error	Z-value	Pr(> |z|)
MA1	-0.40441	0.1644	-2.5031	0.01124

Table 5: Parameter estimation of the ARIMA (2, 1, 4) model for Marine Fish Production.

Coefficients	Estimates	Std. Error	Z-value	Pr(> |z|)
AR1	-0.0194	0.5765	-0.0316	0.9452
AR2	0.6094	0.3812	1.5621	0.115
MA1	0.1618	1.6210	0.1045	0.9183
MA2	-0.9308	1.2027	-0.7756	0.4382
MA3	0.3207	0.4233	0.7533	0.4512
MA4	0.4449	0.8350	0.5022	0.6248



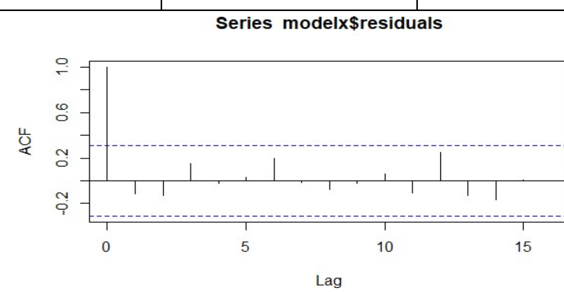
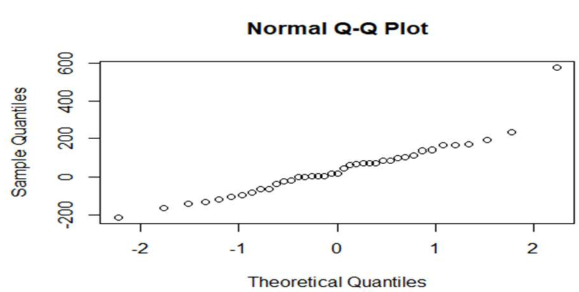


Fig10: ACF (Residuals of marine fish) **Fig11:** ACF (Residuals of total fish**)**



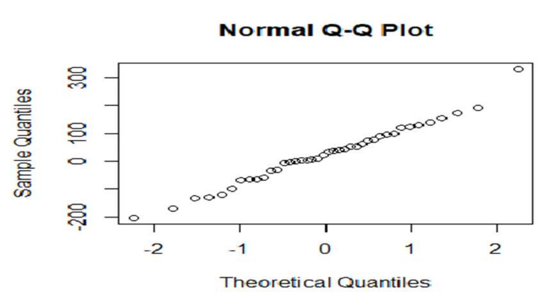


Fig12: Normal Q-Q Plot of the residuals of marine fish. **Fig13:** Normal Q-Q Plot of the residuals of total fish.

Figures 10 and 11 exhibit the residuals' auto-correlation functions. The poor fit of the models is shown by the ACF of the residuals. The R software package was used to estimate the model parameters, and the results are shown in Tables 4 and 5. Table 6 displays the chosen ARIMA models with error measures. This table displays ME, RMSE, MAE, MPE, MAPE, MASE, and ACF1.

ARIMA (0, 2, 1) and ARIMA (0, 2, 1) are the most appropriate ARIMA models for both inland and marine fish production. The data on marine fish has a minimum absolute percentage error (MAPE) of 3.544109, while the data on total fish has a MAPE of 2.822063. We then performed the forecasting for both sets of data.

Additionally, we carried out the forecasting for both the data set. To check the normality we plotted the Normal Q-Q plot for both the data set as shown in Fig12 and Fig13.

Table 6: Error measures for the selected ARIMA models for Marine and Total fish production.

Models	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
ARIMA (0, 2, 1))	6.8896	120.4017	86.9608	0.3524	3.5439	0.8621	-0.0166
ARIMA (0, 2, 1)	47.6933	188.2808	144.6748	0.6656	2.8163	0.5262	-0.1297

Table 7: Marine fish production forecasts for the next 15 years are shown in Table 7, along with the 80% and 95% confidence ranges.

Year	Point Forecast	80%CI		95% CI	
		Lower	Upper	Lower	Upper
2018-2019	3733.35	3574.03	3903.68	3500.17	3978.01
2019-2020	3810.78	3561.12	4031.25	3449.57	4152.79
2020-2021	3847.77	3562.33	4140.61	3420.95	4292.20
2021-2022	3923.36	3570.85	4244.88	3403.96	4431.87
2022-2023	3968.95	3583.06	4344.75	3395.70	4544.82
2023-2024	4025.54	3608.65	4441.84	3390.12	4653.18
2024-2025	4082.14	3626.69	4535.88	3385.82	4778.17
2025-2026	4128.73	3646.34	4631.41	3387.11	4880.67
2026-2027	4194.22	3667.39	4720.15	3390.44	5011.14
2027-2028	4250.51	3680.46	4811.71	3392.40	5119.75

Table 8: Total Fish Production forecasts for the next 15 years, with 80% and 95% confidence ranges.

Year	Point Forecast	80%CI		95%CI	
		Lower	Upper	Lower	Upper
2018-2019	13333.79	13185.20	13680.37	13054.14	13813.43

2019-2020	14161.57	13832.38	14690.77	13605.70	14915.44
2020-2021	15090.36	14468.36	15710.36	14133.09	16039.63
2021-2022	15916.15	15083.91	16750.39	14643.35	17190.95
2022-2023	16743.93	15687.03	17802.84	15124.48	18365.39
2023-2024	17571.72	16270.35	18873.09	15581.44	19562.00
2024-2025	18401.51	16840.59	19960.42	16015.35	20785.66
2025-2026	19218.29	17398.46	21060.12	16427.28	22029.31
2026-2027	20046.08	17940.60	22171.56	16820.21	23291.95
2027-2028	20873.87	18368.60	23300.13	17189.03	24578.70

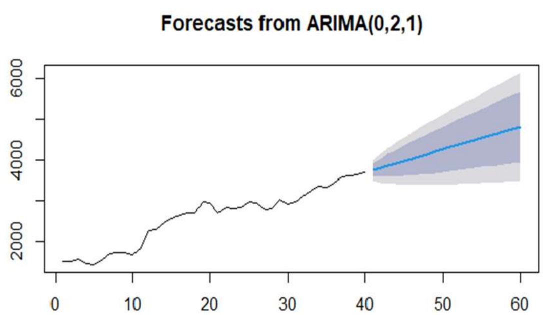


Fig14: Trends of marine fish production in India next 15 years.

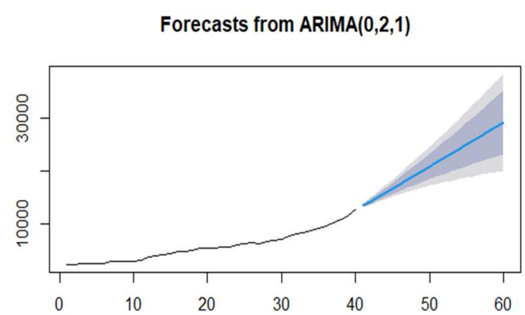


Fig15: Trends of total fish production for the In India for the next 15 years.

The projected figures for India's marine and overall fish production for the next ten years are displayed in Tables 7 and 8. Additionally, the predicted values fall between the 80% and 95% confidence intervals. Additionally, Figures 14 and 15 display the trends of marine and total fish output in India using the ARIMA (0, 2, 1) model for both data sets. Table 7 shows that India's marine fish production trend is gradually declining, whereas Table 8 shows that the country's overall fish production will rise over the next ten years. In 2028, India is expected to produce 4251.591 thousand tonnes of marine fish, for a total of 20883.87 thousand tonnes of fish.

4. Conclusion:

Millions of Indians rely on the fishing industry for both job and money. The annual marine and total fish production in India was fitted to the ARIMA models in this study. The ARIMA (0, 2, 1) models are recognised as the best-fit models for India's marine and overall fish output based on minimal goodness of fit values. We projected the marine and overall fish production for the ensuing decade using these two models. According to the best-fitted models, both areas will see a rise in production over the coming years. An projected 20882.86 thousand tonnes of fish will be produced overall by 2028, with 4250.58 thousand tonnes of fish produced in the maritime sector.

The percentage of total fish production that comes from marine sources has dropped from 71.11% in 1951 to 28.98% in 2018. Inland production has replaced maritime production. We must concentrate on more sophisticated fish producing techniques in order to meet the future demand for fish because India's population is still expanding. The study's conclusions are crucial for entrepreneurs and governments to properly prepare for India's fish output in the future. The opportunities and challenges of marine and total fish production in India are explained in this report for entrepreneurs.

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